OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME LXXVII

CATALOGUE OF PUBLICATIONS OF THE GEOLOGICAL SURVEY OF INDIA AND INDEX OF GEOLOGICAL MAPS

UP TO MARCH 1946

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MEMOIRS

GEOLOGICAL SURVEY OF INDIA

CATALOGUE OF PUBLICATIONS OF THE GEOLOGICAL SURVEY OF INDIA AND INDEX OF GEOLOGICAL MAPS UP TO MARCH 1946.

PREFACE.

Some years have elapsed since it was agreed by the Officers of the Geological Survey that an Index map of India and Burma should be prepared showing those areas of which published geological maps are available, as well as the areas which have been geologically surveyed but of which there were no published maps. After careful consideration it was decided that the proposed Index map could not satisfactorily show more than the areas of which published maps are available and then only with regard to the geological maps published in the Memoirs and Records of the Geological Survey of India. After a further examination of the matter, it was decided that it was most practicable to produce the Index map on the scale of 50 miles to the inch, although this involves its issue in four sheets. The reasons for this were *firstly*, clarity of the Index would be obtained and, *secondly*, the 50 miles to the inch maps are a regular issue of the Survey of India.

In issuing the Index map of the areas geologically surveyed in India and Burma for which geological maps have been published in the Memoirs and Records of the Geological Survey of India, advantage has been taken of the opportunity to prepare a list of all the papers published by the Geological Survey of India in its Memoirs, Records, Palæontologia Indica, etc. It is hoped that this Index map and the accompanying list of publications will enable

geologists of other countries as well as private geologists or geologists attached to industrial organisations in India to see what information they can obtain from the Geological Survey of India. In conclusion it may be added that the Geological Survey of India possesses one of the finest libraries with geological, mining and metallurgical literature in Asia and that responsible enquirers are permitted to consult these works in the library.

MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA.

On the Tertiary and Alluvial deposits of the central portion of the Nerbudda valley, by W. Theobald (Junr.).

On the geological relations, and probable geological age, of the several systems of rocks in Central India and Bengal, by T. Oldham.

VOL. III. Pt. 1, 1861 (*out of print*): On the geological structure and relations of the Raniganj coalfield, Bengal, by W. T. Blanford.

Additional remarks on the geological relations, and probable geological age, of the several systems of rocks in Central India and Bengal, by T. Oldham.

Mineral Statistics of India. I. Coal, by T. Oldham.

Pt. 2, 1864 (*out of print*): On the geological structure and relations of the Southern portion of the Himalayan range between the rivers Ganges and Ravee, by H. B. Medlicott.

VOL. IV. Pt. 1, 1862 (*out of print*): On the Cretaceous and other rocks of the South Arcot, and Trichinopoly districts, Madras, by H. F. Blanford.

Pt. 2, 1864 (*out of print*): On the geological structure of portions of the districts of Trichinopoly, Salem, and South Arcot, Madras, included in sheet No. 79 of the Indian Atlas, by W. King (Junr.) and R. Bruce Foote.

Pt. 3, 1865 (*out of print*): The coal of Assam; results of a brief visit to the coalfields of that Province in 1865: with geological notes on Assam and the hills to the south of it, by H. B. Medlicott.

VOL. V. Pt. 1, 1865 (*out of print*): Geological sections across the Himalayan Mountains, from Wangtu-bridge on the river Sutlej to Sungdo on the Indus: with an account of the formations in Spiti, accompanied by a revision of all known fossils from that district, by F. Stoliczka.

On the gypsum of Lower Spiti, with a list of minerals collected in the Himalayas, 1864, by F. R. Mallet.

Pt. 2, 1866 (*out of print*): On the geology of the Island of Bombay, by A. B. Wynne.

Pt. 3, 1866 (*out of print*): The Jherria coal-field, by T. W. H. Hughes.

Summary of geological observations during a visit to the Provinces- Rupshu, Karnag, South Ladak, Zanskar, Suroo and Dras—of Western Tibet, 1865, by F. Stoliczka.

VOL. VI. Pt. 1, 1867 (*out of print*): Note on the geology of the neighbourhood of Lynyan and Runnee-kote, North-West of Kotree, in Sind, by W. T. Blanford.

On the geology of a portion of Cutch, by W. T. Blanford.

Pt. 2, 1867. *Reprinted* 1908 and 1921 (*price* Rs. 2): The Bokaro coalfield, by T. W. H. Hughes.

The Ramgurh coalfield, by V. Ball.

On the Traps and Intertrappean beds of Western and Central India, by W. T. Blanford.

Pt. 3, 1869 (*price* Rs. 2 as. 8): On the geology of the Taptee and Lower Nerbudda valleys, and some adjoining districts, by W. T. Blanford.

On the occurrence of frog-beds at a locality hitherto concealed, but exposed now by re-clamation works in Bombay Island, December 1867, by A. B. Wynne.

Osteological notes on *Oxyglossus pusillus* (*Rana pusilla*, Owen), from the Tertiary frog-beds in the Island of Bombay, by F. Stoliczka.

VOL. VII. Pt. 1, 1869 (*price* Rs. 3): On the Vindhyan series, as exhibited in the North-Western and Central Provinces of India, by F. R. Mallet.

Mineral Statistics of India—Coal, by T. Oldham.

Geological sketch of the Shillong Plateau in North-Eastern Bengal, by H. B. Medlicott.

Pt. 2, 1870 (*out of print*): The Kuhurbari coalfield, by T. W. H. Hughes.

The Deoghur coalfields, by T. W. H. Hughes.

Pt. 3, 1871 (*out of print*): On the geological structure of the Country near Aden, with reference to the practicability of sinking Artesian wells, by F. R. Mallet.

The Káránpurá coalfields, by T. W. H. Hughes.

VOL. VIII. Pt. 1. 1872 (*price* Rs. 4): On the Kadapah and Karnúl formations in the Madras Presidency, by W. King (Junr.).

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The Daltonganj coalfield, by T. W. H. Hughes.

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VOL. IX. Pt. 1, 1872 (*price* Rs. 4): Memoir on the geology of Kutch, to accompany a map compiled by A. B. Wynne and F. Fedden, during the seasons 1867-68 and 1868-69, by A. B. Wynne.

Pt. 2 (*price* Re. 1): Description of the geology of Nágpúr and its neighbourhood, by W. T. Blanford.

The geology of Mount Sirban, in the Upper Punjab, by W. Waagen and A. B. Wynne.

On the occurrence of Ammonities, associated with Ceratites, and Goniatites in the Carboniferous deposits of the Salt Range, by W. Waagen.

VOL. X. Pt. 1, 1873 (*price* Rs. 3): On the geology of parts of the Madras and North Arcot districts lying north of the Palar river, and included in Sheet 78 of the Indian Atlas, by R. Bruce Foote.

Notes on the Sátpurá coal basin, by H. B Medlicott.

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VOL. XI. Pt. 1. 1874 (*price* Rs. 2): On the geology and mineral resources of the Darjiling district and the Western Duars, by F. R. Mallet.

Pt. 2. 1875 (*price* Rs. 3): The Trans-Indus salt region in the Kohát district, by A. B. Wynne. With an Appendix on the Kohát mines or quarries, by H. Warth.

VOL. XII. Pt. 1, 1876 (*price* Rs. 3): The geological features of the South Mahratta country and adjacent districts, by R. Bruce Foote.

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VOL. XV. Pt. 1. 1878 (*out of print*): On the Auranga and Hutar coalfields and the iron-ores of Palamow and Toree, by V. Ball.

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VOL. XVI. Pt. 1. 1879, *Reprinted* 1930 (*price* Rs. 3): On the geological structure of the Eastern Coast from latitude 15° northward to Masulipatam, by R. Bruce Foote.

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On cobaltite and danaite from the Khetri Mines, Ráj-putána; with some remarks on Jaipurite (Syepoorite), by F. R. Mallet.

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Submerged forest on Bombay island, observations by G. E. Ormiston.

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Geology of North-West Káshmír and Khágán (being sixth notice of geology of Káshmír and neighbouring territories), by R. Lydekker.

On some Gondwána Labyrinthodonts, by R. Lydekker.

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On the Genus *Richthofenia*, Kays. (*Anomia Lawrenciana*, Koninck), by W. Waagen.

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Note on the occurrence of *Mastodon angustidens* in India, by R. Lydekker.

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Note on the Cretaceous coal-measures at Borsora in the Khasia Hills, near Laour in Sylhet, by T. H. D. La Touche.

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On the microscopic structure of some Sub-Himalayan rocks of tertiary age, by Colonel C. A. McMahon.

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Considerations on the smooth-water anchorages, or mud banks of Narrakal and Alleppy on the Travancore Coast, by W. King.

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Notes on the geology of the Chuári and Sihunta parganahs of Chamba, by Colonel C. A. McMahon.

Note on the occurrence of the genus *Lyttonia,* Waag., in the Kuling series of Kashmir, by R. Lydekker.

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Section along the Indus from the Pesháwar valley to the Salt Range, by W. Waagen.

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Note on lignite near Ráipur, Central Provinces, by P. N. Bose.

The turquoise mines of Nishâpúr, Khorassan, by A. Hontum Schindler.

Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan, by F. R. Mallet.

Report on the Langrin coalfield, South-West Khasia Hills, by T. H. D. La Touche.

Additional notes on the Umaria coalfield (South Rewah Gondwána basin), by T. W. H. Hughes.

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Notes on auriferous sands of the Subansiri river; - Pondicherry lignite;- and phosphatic rocks at Musuri, by W. King.

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Note on coal and limestone in the Doigrung river, near Golaghat, Assam, by T. H. D. La Touche.

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Note on a second species of Siwalik camel (*Camelus antiquus*, *nobis* ex Falc. and Caut. M. S.), by R. Lydekker.

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Notes on the result of Mr. H. B. Foote's further excavations in the Billa Surgam caves, by R. Bruce Foote.

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Memorandum on the discussion regarding the boulder-beds of the Salt-Range, by H. B. Medlicott.

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Memorandum on the Malanjkhandi copper ore, in the Balaghat district, Central Provinces, by W. King.

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Analysis of gold-dust from the Meza valley, Upper Burma, by R. Romanis.

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Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar Bawar and Tiri-Garhwal, by C. S. Middlemiss.

Notes on the geology of the Garo Hills, by T. H. D. La Touche.

Note on some Indian image-stones, by Colonel C. A. McMahon.

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Analysis of phosphatic nodules from the Salt-Range, Punjab, by H. Warth.

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Note on the Echinoidea of the Cretaceous series of the Lower Narbada valley, with remarks upon their geological age, by P. Martin Duncan.

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Notes on the microscopic structure of some specimens of the Rajmahal and Deccan traps, by Colonel C. A. McMahon.

Some notes on the dolerite of the Chor, by Colonel C. A. McMahon.

On the identity of the Olive series in the east, with the speckled sandstone in the west, of the Salt-Range, in the Punjab, by H. Warth.

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Note on the "Lalitpur" meteorite, by F. R. Mallet.

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Some remarks on pressure metamorphism with reference to the foliation of the Himalayan gneissose-granite, by Colonel C. A. McMahon.

A list and index of papers on Himalayan geology and microscopic petrology, by Colonel C. A. McMahon, published in the preceding volumes of the Records of the Geological Survey of India.

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The Birds-nest or Elephant Island, Mergui Archipelago, by Commander Alfred Carpenter.

Memorandum on the result of an exploration of Jessalmer, with a view to the discovery of Coal, by R. D. Oldham.

A facetted pebble from the Boulder Bed ("Speckled Sandstone") of Mount Chel in the Salt-Range in the Punjab, by H. Warth.

Examination of nodular stones obtained by trawling off Colombo, by E. J. Jones.

Part 2 (out of print).—Award of the Wollaston Gold Medal, Geological Society of London, 1888.

The Dharwar system, the chief auriferous rock series in South India, by R. Bruce Foote.

Notes on the igneous rocks of the districts of Raipur and Balaghat, Central Provinces, by P. N. Bose.

Report on the Sangar Marg and Mehowgala coalfields, Kashmir, by T. H. D. La Touche.

Part 3 (out of print).—The manganese-iron and manganese-ores of Jabalpur, by P. N. Bose.

"The Carboniferous Glacial Period", by Oberbergrath Prof. Dr. W. Waagen. Translated by R. Bruce Foote.

The sequence and correlation of the pre-Tertiary sedimentary formations of the Simla region of the Lower Himalayas, by R. D. Oldham.

Part 4 (out of print).—Notes on Indian Fossil Vertebrates, by R. Lydekker.

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Notes on some mica-traps from Barakar and Raniganj, by P. N. Bose.

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On flexible sandstone or itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility, by R. D. Oldham.

Notes on Siwalik and Narbada Chelonia, by R. Lydekker.

Part 2 (out of print).—Note on Indian steatite, compiled by F.R. Mallett.

Distorted pebbles in the Siwalik conglomerate, by C. S. Middlemiss.

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Notes on Dr. W. Waagen's "Carboniferous Glacial Period", by A. B. Wynne, and Ottokar Feistmantel.

Report on the oilfields of Twingoung and Beme, Burma, by Fritz Noetling.

The gypsum of the Nehal Nadi, Kumaun, by C. S. Middlemiss.

On some of the materials for pottery obtainable in the neighbourhood of Jabalpur, and of Umaria, by F. R. Mallet.

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Note on the discovery of trilobites by Dr. H. Warth in the neobolus beds of the Salt-Range, by W. King.

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Report on the Cherra Poonjee coalfield, in the Khasia Hills, by T. H. D. La Touche.

Note on a cobaltiferous matt from Nepál, by E. J. Jones.

The President of the Geological Society of London on the International Geological Congress of 1888.

Tin-mining in Mergui district, by T. W. H. Hughes.

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Note on the pelvis of a Ruminant from the Siwaliks, by R. Lydekker.

Recent assays from the Sambhar salt lake in Rajputana, by H. Warth.

The manganiferous iron and manganese ores of Jabalpur, by P N. Bose.

On some palagonite-bearing traps of the Rajmahal Hills, and Deccan, by C. S. Middlemiss.

Notes on tin smelting in the Malay Peninsula, by T. W. H. Hughes.

Provisional index of the local distribution of important minerals, miscellaneous minerals, gem stones, and quarry stones in the Indian Empire, by W. King.

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Report on the Lakadong coalfield, Jaintia Hills, by T. H. D. La Touche.

On the pectoral and pelvic girdles and skull of the Indian Dicynodonts, by R. Lydekker.

Note on certain vertebrate remains from the Nagpur district, by R. Lydekker. (With description of a fish-skull, by A. Smith Woodward.)

Crystalline and metamorphic rocks of the Lower Himalaya, Garhwál and Kumaun, Section IV, by C. S. Middlemiss.

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The sapphire mines of Kashmir, by T. H. D. La Touche.

The supposed matrix of the diamond at Wajra Karur, Madras, by Philip Lake.

Notes on the Sonapet goldfield, by Fritz Noetling.

Field notes from the Shan Hills (Upper Burma), by Fritz Noetling.

A description of some new species of Syringosphæridæ, with remarks upon their structures, etc., by P. Martin Duncan.

Part 3 *(out of print)*. -Report on the geology and economic resources of the country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan, by R. D. Oldham.

Report of a journey through India in the winter of 1888-89, by Dr. Johannes Walther. (Translated from the German, by R. Bruce Foote.)

Report on the coalfields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills, by T. H. D. La Touche.

Further note on Indian steatite, by J. R. Royle.

Provisional index of the local distribution of important minerals, miscellaneous minerals, gem stones, and quarry stones in the Indian Empire, by W. King.

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Note on some fossil Indian bird bones, by R Lydekker.

The Darjiling coal between the Lisu and the Ramthi rivers, explored during season 1889-90, by P. N. Bose.

The basic eruptive rocks of the Kadapah area, by Philip Lake.

The deep boring at Lucknow, by R. D. Oldham.

Preliminary note on the coal seam of the Dore ravine, Hazara, by C. S. Middlemiss.

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Notes on the geology of the Salt Range of the Panjab, with a re-considered theory of the origin and age of the Salt Marl, by C. S. Middlemiss.

On veins of graphite in decomposed gneiss (laterite) in Ceylon by Dr. Johannes Walther. (Translated by R. B. Foote.)

Extracts from the journal of a trip to the glaciers of the Kabru, Pandim, etc., by P. N. Bose.

The salts of the Sambhar Lake in Rajputana, and of the saline efflorescence called 'Reh' from Aligarh in the N.-W. Provinces, by H. Warth.

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Report on the coalfields in the Northern Shan States, by Fritz Noetling.

Note on the reported Namséka ruby-mine in the Mainglôn State, by Fritz Noetling.

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Death of Dr. P. Martin Duncan, M.B. (London), F.R.S., F.L.S., F.G.S., etc., by W. King.

Contributions to the study of the pyroxenic varieties of gneiss and of the scapolite-bearing rocks, by M. Al. Lacroix.--Ceylon and Salem. (Translated by F. R. Mallet.)

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Note on the geology and mineral resources of Sikkim, by P. N. Bose.

Chemical and physical notes on rocks from the Salt Range, Punjab, by T. H. Holland.

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Note on the occurrence of *Velates schmideliana* Chemn., and *Provelates grandis* Sow. sp., in the Tertiary formation of India and Burma, by Fritz Noetling.

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Report on the Eleventh International Geological Congress, held in Stockholm in August 1910, by L. L. Fermor.

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Notes on Indian aerolites recorded since 1906, by G. de P. Cotter.

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Notes on the relationship of the Himalaya to the Indo-Gangetic plain and the Indian Peninsula, by H. H. Hayden.

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Further notes on the species "Camarocrinus asiaticus" from Burma, by F. R. C. Reed.

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A carbonaceous ærolite from Rajputana, by W. A. K. Christie.

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A Lower Cretaceous fauna from the Himalayan Gieumal Sandstone, together with a description of a few fossils from the Chikkim series, by Albrecht Spitz (Vienna). (Translated by E. Vredenburg.)

Further description of *Indarctos salmontanus* Pilgrim, the new genus of Bear from the Middle Siwaliks, with some remarks on the fossil Indian Ursidæ, by Guy E. Pilgrim.

On the probable future beheading of the Son and Rer rivers by the Hasdo, by L. L. Fermor.

Part 4.—Notes on the Salt Deposits of the Cis-Indus Salt Range, by W. A. K. Christie.

Description of teeth referable to the Lower Siwalik-Creodont genus *Dissopsalis*, Pilgrim, by Guy E. Pilgrim.

Notes on some glaciers of the Dhauli and Lissar valleys, Kumaon Himalaya, September 1912, by Captain John L. Grinlinton.

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The dentition of the Tragulid Genus *Dorcabune*, by Guy E. Pilgrim.

On hematite crystals of corundiform habit from Kajlidongri, Central India, by L. L. Fermor.

Part 4.—Geology of the country near Ngahlaingdwin, Minbu district, Burma, by Cesare Porro (with geological map, by C. Porro and R. Lewer, and with footnotes and Appendix, by G. de P. Cotter).

Notes on the geology of Chitral, Gilgit and the Pamirs, by H. H. Hayden.

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Some newly discovered Eocene mammals from Burma, by Guy E. Pilgrim, and G. de P. Cotter.

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Flemingostrea, an eastern group of Upper Cretaceous and Eocene *Ostreidæ*: with descriptions of two new species, by E. Vredenburg.

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A fossil wood from Burma, by Miss Ruth Holden.

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A revised classification of the Gondwana system, by G. de P. Cotter.

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Preliminary note on some recent mammal collections from the Basal beds of the Siwaliks, by Guy E. Pilgrim.

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Les Echinides des "Bagh beds," par R. Fourtau.

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The support of the mountains of Central Asia (being an Appendix to the Memoir on the structure of the Himalayas, and of the Gangetic plain, as elucidated by geodetic observations in India), by R. D. Oldham.

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The submerged forest at Bombay, by T. H. D. La Touche.

On some Infra-Trappeans and a silicified lava from Hyderabad, S. India, by K. A. K. Hallowes.

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The potash salts of the Punjab Salt Range and Kohat, by Murray Stuart.

Suggestions regarding the origin and history of the rock-salt deposits of the Punjab and Kohat, by Murray Stuart.

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On the inclination of the thrust-plane or reversed fault, between the Siwalik and Murree zone of formations, near Kotli, Jammu Province, by C. S. Middlemiss.

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The galena deposits of North-Eastern Putao, by Murray Stuart.

Part 4 (*out of print*).—On pitchblende, monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa, by G. H. Tipper.

Natural gas in bituminous salt from Kohat, by Murray Stuart.

The mineral resources of the Central Provinces, by L. L. Fermor.

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Indian fossil viviparæ, by N. Annandale.

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Unionidæ from the Miocene of Burma, by E. Vredenburg and B. Prashad.

VOL. LII, 1921.

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VOL. LIII, 1921.

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The antimony deposit of Thabyu, Amherst district, Burma, by A. M. Heron.

Note on some antimony deposits of the Southern Shan States, by H. Cecil Jones.

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Comparative diagnoses of Conidæ and Cancellariidæ from the Tertiary formations of Burma, by E. Vredenburg.

On the stratigraphy, fossils and geological relationships of the Lameta beds of Jubbulpore, by C. A. Matley.

The rocks near Lameta ghat (Jubbulpore district), by C. A. Matley.

Part 3 (out of print).—Frederick Richmond Mallet, F.G.S. [Born 10th February 1841: Died 24th June 1921, by E. H. Pascoe.

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The mineral resources of Bihar and Orissa, by L. L. Fermor.

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The sulphur deposits of Southern Persia, by Guy E. Pilgrim.

A zone-fossil from Burma: Ampullina (Megatylotus) birmanica, by E. Vredenburg.

VOL. LIV, 1922.

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Contributions to the geology of the Province of Yunnan in Western China: 6. Traverses between Tali Fu and Yunnan Fu, by J. Coggin Brown.

The geology of the Takki Zam valley, and the Kaniguram-Makin area, Waziristan, by Captain Murray Stuart.

A note on the geology of Thayetmyo and neighbourhood, including Padaukbin, by G. de P. Cotter, with a map by the late H. S. Bion.

The occurrence of bitumen in Bombay Island, by Cyril S. Fox.

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Revision of some fossil Balanomorph Barnacles from India and the East Indian Archipelago, by Thomas H. Withers.

Contributions to the geology of the Province of Yunnan in Western China: 7. Reconnaissance surveys between Shun-ning Fu, Pu-e'rh Fu Ching-tung T'ing and Ta-li Fu, by J. Coggin Brown.

Contributions to the geology of the Province of Yunnan in Western China: 8. A traverse down the Yang-tze-chiang valley from Chin-chiang-kai to Hui-li Chou, by J. Coggin Brown.

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Ochre pits around Daroli, by D. N. Wadia.

Note on the oil-shales of Mergui, by M. Vinayak Rao.

Note on the age of the limestone opposite Martaban Railway Station, Thaton district, Burma, by G. de P. Cotter.

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Geological traverses from Assam to Myitkyina through the Hukong valley, Myitkyina to Northern Putao; and Myitkyina to the Chinese Frontier, by Murray Stuart.

Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma, by the late E. Vredenburg.

Mineral resources of the Kolhapur State, by H. Cecil Jones.

Notes on the Kunghka and Manmaklang iron ore deposits, Northern Shan States, Burma, by E. L. G. Clegg.

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Indian Tertiary gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species, by the late E. Vredenburg.

On the geological interpretation of some recent geodetic investigations (being a second appendix to the Memoir on the structure of the Himalayas and of the Gangetic plain as elucidated by geodetic observations in India), by R. D. Oldham.

Part 2.—Ernest (Watson) Vredenburg, B.-es-L., B.-es-Sc. (France), A.R.S.M., A.R.C.S., F.G.S., F.A.S.B. Born 17th April 1870: Died 12th March 1923, by E. H. Pascoe.

Fossil molluscs from the oil-measures of the Dawna Hills, Tenasserim, by N. Annandale.

Note on an armoured Dinosaur from the Lameta beds of Jubbulpore, by C. A. Matley.

On some fossil forms of Placuna, by the late E. Vredenburg.

On the phylogeny of some Turbinellidæ, by the late E. Vredenburg.

Recent falls of ærolites in India, by H. Walker.

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The china clay of Karalgi, Khanapur, Belgaum district, by K. A. K. Hallowes.

Part 4.—Henry Hubert Hayden: Born July 25th, 1869. Died August 1923, by E. H. Pascoe.

The oil-shales of Eastern Amherst, Burma, with a sketch of the geology of the neighbourhood, by G. de P. Cotter.

Provisional list of Palæozoic and Mesozoic fossils collected by Dr. Coggin Brown in Yun-nan, by F. R. C. Reed.

Note on the fall of three meteoric irons in Rajputana on the 20th May 1921, by L. L. Fermor.

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A freshwater fish from the oil-measures of the Dawna Hills, by the late N. Annandale, and S. L. Hora.

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On a calcareous alga belonging to the *Triploporelleæ* (*Dasycladaceæ*) from the Tertiary of India, by John Walton.

Froth flotation of Indian coals, by W. Randall.

Submarine mud eruptions off the Arakan Coast, Burma, by J. Coggin Brown.

Notes on Cretaceous fossils from Afghanistan and Khorasan, by the late H. S. Bion, with an Introduction by J. Coggin Brown.

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The Maunypur salt works, by J. A. Dunn.

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VOL. LVIII, 1925-26.

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A fossil tree in the Panchet series of the Lower Gondwanas near Asansol, by E. J. Bradshaw: with a palæontological description, by B. Sahni.

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Note on the constitution of glauconite and celadonite, by L. L. Fermor.

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Fossiles recueillis par Hayden dans le Kashmir en 1906 et les Pamirs en 1914; leur description, par H. Douvillé.

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The petrography of rocks from the Girnar and Osham Hills, Kathiawar, by M. S. Krishnan.

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The zonal distribution and description of the larger foraminifera of the middle and lower Kirthar series (middle Eocene) of parts of Western India, by W. L. F. Nuttall.

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Remarks on Carter's genus *Conulites-Dictyoconoides*, Nuttall with descriptions of some new species from the Eocene of North-West India, by Major L. M. Davies.

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Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa, by M. S. Krishnan.

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The lower canine of Tetraconodon, by Guy E. Pilgrim.

The geology of Bundi State, Rajputana, by A. L. Coulson.

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The Barakar ironstone boundary near Begunia, Raniganj coalfield, by Cyril S. Fox.

The Raniganj-Panchet boundary near Asansol, Raniganj coalfield, by Cyril S. Fox.

A Permo-Carboniferous marine fauna from the Umaria coalfield, by F. R. C. Reed.

The geology of the Umaria coalfield, Rewah State, Central India, by E. R. Gee.

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Miscellaneous Notes :—

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Barytes in Orchha State, by A. L. Coulson.

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Actinodon risinensis, n. sp. in the Lower Gondwanas of Vihi district, Kashmir, by D. N. Wadia, and W. E. Swinton.

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INDEX MAP OF INDIA AND BURMA SHOWING MAPS PUBLISHED BY THE GEOLOGICAL SURVEY OF INDIA.

The Index comprises four map sheets on the scale of 50 miles to the inch as under:—

Sheet 1.—North-western India.

Sheet 2.—North-eastern India and northern Burma.

Sheet 3.—Southern India.

Sheet 4.—Orissa and southern Burma.

On the Index map the limits of the areas covered by geological maps published by the Geological Survey of India are marked by full or broken lines in one of the three colours, green, red or blue. The following notation has been found convenient to show the respective scales of the published maps:—

Maps less than 4 miles to the inch—Broken green.

Maps 4 miles to the inch—Full green.

Maps 8 miles to the inch—Full red.

Maps 16 miles to the inch—Full blue.

Maps 32 miles and more to the inch—Broken blue.

The publication in which any particular map has appeared may be ascertained as in the following two examples:—

R. 54, 2 (in full red). This map is on the scale of 8 inches to the mile and was published in *Records*, Volume LIV, Pt. 2.

M. 39, 1 (in broken blue). This map is on the scale of 32 miles to the inch and was published in *Memoirs*, Volume XXXIX, Pt. 1.

In addition a considerable part of India has been mapped on the scale of one mile to the inch. The majority of these maps have not been published, but copies of some may be obtained from the Director, Geological Survey of India at the cost of the materials used and of the labour of hand reproduction.

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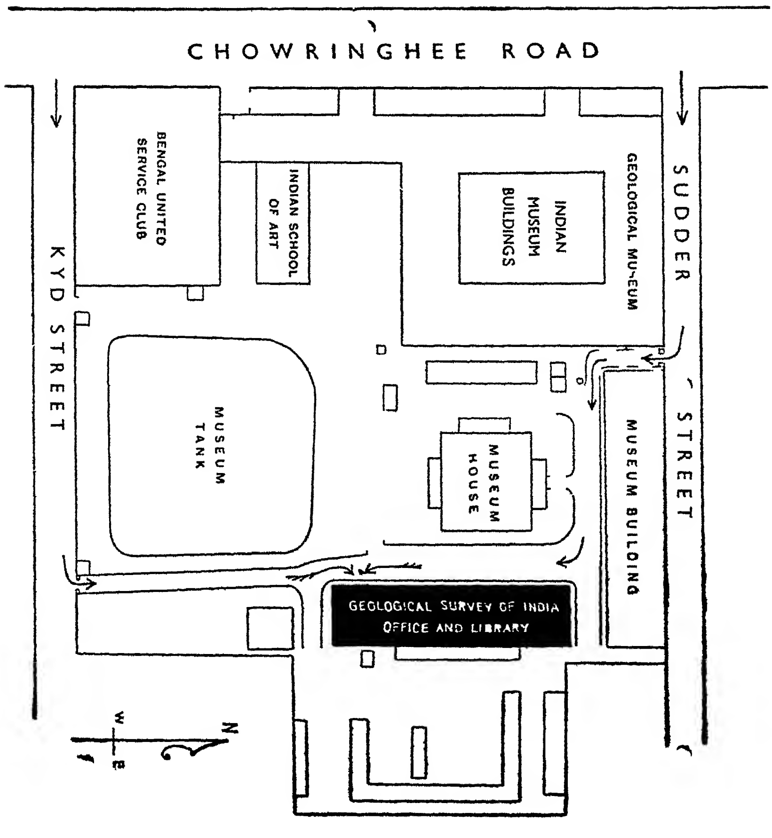

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MEMOIRS
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VOLUME LXXVIII.

THE ECONOMIC GEOLOGY AND MINERAL RESOURCES OF BIHAR PROVINCE

BY J. A. DUNN, D. Sc., D.I.C., F.G.S., F.N.I.,

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MEMOIRS

GEOLOGICAL SURVEY OF INDIA

THE ECONOMIC GEOLOGY AND MINERAL RESOURCES OF BIHAR PROVINCE

By J. A. DUNN, D.Sc., D.I.C., F.G.S., F.N.I.,

Superintending Geologist, Geological Survey of India.

PART I.—ECONOMIC ASPECTS OF GEOLOGY IN BIHAR.

CHAPTER I.

INTRODUCTION.

Object of the Memoir.

A summary of the known mineral resources of Bihar and Orissa was published by the Geological Survey of India in 1921. Since then (in 1936) Orissa has been separated from Bihar thus forming two provinces, and as a large amount of additional knowledge of the economic minerals of Bihar has accumulated, the condition of the mineral industry in this province has entirely changed.

It has been the writer's privilege, for some 20 years, to have been closely concerned with almost all aspects of the mineral industry and geological advice in Bihar. It has been suggested that a moderately complete summary of the experience gained and of the views formed may be of value in these days of rapid development. In writing this account the primary object has been to make known the present actual position of the mineral industry and to indicate in which direction further development should be encouraged. In addition, the author has endeavoured to state, explicitly and unequivocally wherever it has been possible, his opinion of the various mineral resources, based on his experience.

This account is written with the intention of providing information from many points of view related to the industry. The prospector is informed of those minerals for which he may usefully search within the province, and he is given hints which, it is hoped, will help to guide him in his search. He is definitely informed of those minerals for which no market may be expected. The mineral industry is informed of the resources which each branch of it may expect to find available in the province, and information on related minerals may assist each industry to determine in which direction it may expand, or to what extent it may secure local supplies of materials which it may require in the furtherance of its main industry. The research worker, it is hoped, will find information which will provide him with lines of enquiry to pursue in support of the mineral development of the province.

Some aspects of the relation of the State to the mineral industry are reviewed. The mineral owners, whether they be zamindars or Government, may find herein information which will help them to a balanced appreciation of the real value of the mineral deposits which they may lease out. Not uncommonly, the monetary value of a mineral deposit has been grossly exaggerated and its proper development accordingly hindered. At times the intrinsic value of mineral occurrences has been under-appreciated and Government, in particular, has not obtained that revenue to which it should have been entitled.

The author has endeavoured to place on record also his views on such matters as rents, royalties and taxation affecting mineral development, and on geological questions affecting engineering, forestry and agriculture in Bihar, so that district officers and Government officials of various departments may find herein information which may prove a helpful guide in their work. To such officials, however, the fact must be stressed that geological problems must be treated individually, and that the information provided should not be substituted for the services of a geologist. On the contrary, it is hoped that this account will lead to an increasing use being made, on the part of the provincial Government, of the experience and advice of the geologist in *all* questions related to the mineral industry

A further object has been to provide information which will assist Government to a precise understanding of the exact capabilities of the province for further mineral development, and to

appreciate those minerals on which they should concentrate encouragement of further efforts, and those which they should ignore or leave entirely to industry to develop. The author's views on the form which Government encouragement should take may, perhaps, be regarded as apposite.

It is not possible to describe in great detail the large number of individual mineral occurrences within the province. Detailed accounts of them are scattered over many publications, relatively few of which are easily obtainable throughout the province. However, the works listed in the Bibliography provided at the end of the account of each mineral, may be consulted by those who are anxious to obtain a more complete knowledge of individual mineral deposits. By a judicious use of the Locality Index readers should find it possible to obtain full information on each district, locality, and mineral. The writer is indebted to his colleague, Dr. L. A. N. Iyer, for checking the coordinates and preparing the Locality Index.

The memoir has been divided into two parts, Part I dealing in general terms with the economic aspects of geology in Bihar, Part II dealing only with the mineral occurrences. Chapters on Physiography and Geology in Part I may at first be thought a little too theoretical for a work of this nature, but some knowledge of these two subjects is essential if the varied applications of geology to engineering, agriculture, forestry and industry generally are to be appreciated. No connected account of the physiography of the province has ever been attempted previously, but the subject is assuming increasing importance.

The memoir will illustrate, perhaps, the very wide range of inquiries which the geologist is expected to undertake. In India, there has been little opportunity for specialisation in certain branches of geology mainly because the number of geologists available is so small, but such specialisation would be advantageous in the future, and would limit the work of individual geologists to inquiries with which they can cope with greater authority.

Growth of Bihar's mineral industry.

Bihar is easily the richest mineral province in India. This is true not only of the monetary value of the minerals produced but also of the remarkable diversity of the minerals which are available. In Table 1 a list is given of the principal minerals produced during 1939 of which records are available, and their value, the comparative totals for all India being also provided. For 1939, of a total

mineral production in India valued at Rs. 35,55,90,763 Bihar was responsible for 39·4 percent or Rs. 14,01,64,372.

TABLE 1.—*Production of principal minerals, 1939.*

Name of Mineral.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1. Coal	14,787,661	4,84,02,895	27,768,761	9,87,23,916
2. Pig-iron	760,366 (a)	3,80,04,800 (a)	863,658	4,31,82,900 (a)
3. Stee	298,148 (a)	3,99,51,832 (a)	741,717	9,93,90,078 (a)
4. Mica	85,662 (b)	38,67,280	139,758 (b)	51,80,934
5. Copper (refined.)	6,535	71,75,430	6,535	71,75,430
6. Limestone and kankar.	500,364	6,61,258	3,915,345	46,55,813
7. Clays	18,361	2,55,159	328,603	5,24,909
8. Manganese ore.	35,803	8,33,587 (d)	844,663	1,83,65,038 (d)
9. Chromite	4,476	1,01,218	49,136	6,35,511
10. Kyanite	766	11,490	9,918	1,55,351
11. Steatite	955	5,591	22,259	2,03,841
12. Gold	..	..	314,515 (c)	3,24,34,364
13. Saltpetre	1,181 (e)	(f)	10,739	(f)

(a) Estimated from Bihar ore. (b) In cwts. (c) In ounces. (d) Export f.o.b. value. (e) Figures for the official year 1939-40, and include 717 tons from the Gorakhpur Circle. (f) Not available.

It will be observed that a large part of the value of Bihar's mineral production is represented by coal, and, indeed, it is apposite to remark that much of India's industry, at least in the eastern part of the country, is based upon Bihar's coal supplies, which have provided adjacent manufacturing centres with a remarkably cheap source of power. The fortunate circumstance that vast deposits of high-grade iron-ore occur within the bounds of the same province have permitted the rise of a great and important industry—iron and steel smelting—at two centres, one at Jamshedpur within the province, the other near Asansol just over the border of the province, in Bengal. In 1910 the site of Jamshedpur was an expanse of jungle at the confluence of two rivers, the Kharkai and the Subarnarekha, overlooked to the north by the great mass of Dalma hill rising to 3,000 feet. To-day, in spite of the atmosphere normally associated with such a smelting industry, the site is covered by a model town, a credit to India, and occupied by about 100,000 people. Around the smelters at Jamshedpur have grown several subsidiary industries and the town is rapidly expanding, but even to-day it is the greatest metallurgical centre in the country.

Within the province, near Ghatsila in Singhbhum, there is also the only copper smelting industry in India, supplying a large proportion of the country's demand for brass.

From the central part of the province, in Hazaribagh district particularly, comes most of the world's production of the better grades of mica and of mica splittings; indeed it might be said that Bihar holds control of the world's supply of mica. In recent years the production of mica from Bihar has risen to nearly three times its total of 25 years ago.

These are the main mineral industries, providing work for many thousands of people, and aiding in the fundamental development of the country. Their value is to be counted ultimately not in the bare quotations of selling prices or pit's mouth values of the minerals, but in the deep-rooted and widespread effect which they have on India's other industries, and on the ever-improving welfare, health and standard of living of the people and the capacity of the country to expand its resources in other directions. Even the commoner minerals are playing their part, such as the rocks which provide material for construction of the gradually expanding road system, and for the greater part of our building construction. It may be said with truth that India lives on her agriculture but develops on her minerals, and to this development Bihar offers the greatest contribution.

CHAPTER II.

PHYSIOGRAPHY.

The description of the physiography of Bihar, which follows, is perhaps fuller than might be expected in a work of this nature. There has, however, never been any serious attempt to study the crustal movements of this region as a whole. The author has previously written two brief accounts of movements in Singhbhum and across the northern edge of the Chota Nagpur plateau. No other accounts are available.

Of recent years the examination of stream and river activity, of soil erosion and climatic conditions have become of increasingly greater importance to those interested in engineering, forestry, and agriculture. Some understanding of the causes underlying stream activity and land surface movements is essential, and it is hoped that the following outline will serve as a stimulus to an intensive study of the movement of streams and land surfaces throughout the province. It would form a lifetime study for several geologists, and if the work were done in collaboration with engineers, foresters, and agriculturists, valuable results should accrue. It is a study, however, in which logical and clear thinking is essential, in which pre-conceived ideas must be brushed aside, and will require a prolonged personal and detailed acquaintance with the whole province.

Bihar province extends from the foot of the Himalaya for a distance of some 360 miles to the south, and has a maximum east-west width of about 290 miles. This area may be divided into two major parts: (1) The vast Gangetic plains of North Bihar, and (2) the plateaux, plains, and dissected country of Central and South Bihar or Chota Nagpur.

The Gangetic plains consist of alluvial deposits which extend to a variable but unknown maximum depth. Their greatest depth is thought to be at least 6,000 feet but other estimates have multiplied this more than five times. The deepest part appears to form a trough extending W. N. W.—E. S. E. through Motihari. South from this, the alluvium gradually thins until it abuts against the rock outcrops forming the edge of the Peninsula, south of the Ganges.

This alluvial material has, undoubtedly, been shed mainly from the towering Himalaya to the north, but partly from the lower-lying

Peninsular surface to the south. The mechanism by which such a great depth of alluvium can have accumulated has, however, been variously interpreted. Briefly, the various interpretations may be grouped into (*a*) the infilling of a pre-existing great depression and (*b*) the accumulation of sediments on a gradually or intermittently subsiding surface. The latter view is that which has been largely accepted to-day.

The Gangetic plain is traversed from east to west, in its southern part, by the Ganges. North of the Ganges the plain is traversed by a series of south-flowing tributary streams. All of these streams have their headwaters in the Himalaya and. before they debouch through the hills, have a steep gradient, are torrential, and carry a heavy load of sediments. On emerging from the hills the gradients suddenly flatten, the swiftness of the current is checked, and, unable to carry the same load, the streams tend to deposit their sediments. In times of flood the flat-graded stream channels are unable to carry within their banks all the water which debouches through the hills and the flood-waters, which spread far beyond the river banks, deposit their load of sediment over the surrounding country.

Partly in consequence of their flat gradient, the streams tend to take a pronounced meandering course, thus still further reducing their gradient and lowering their capacity for holding the run-off between their banks. Hence, in times of flood, there is a constant tendency for streams to change their courses, to cut across the meanders. and to split into several channels. In this way part of the surface alluvium is itself being redistributed.

Without some subsidence streams of such gentle gradient cannot indefinitely continue to build up sediments over such a wide area of country, and the tendency as a whole, in this area, must be towards gradual or intermittent sinking, keeping pace more or less with deposition of sediment. It must not be supposed however, that no uplift takes place also—it is possible that periods of slight uplift may alternate with periods of greater subsidence. Such uplift, if widespread, would tend to cause scouring of river beds.

A study of the river and surface characteristics, from the foot of the Himalaya to the Ganges, suggests that, at the present day, the general tendency is for uplift north of a line joining Motihari and Purnea, and subsidence south of that line. North of this line the alluvium has an aspect different from that to the south; it is commonly more conglomeratic (particularly north of Purnea) and

is a distinctly older land surface standing at a definitely higher level. Apart from major rivers like the Kosi, streams here show less tendency to flooding, and prefer rather to scour their beds and banks. In this way, particularly in the valley of the Kosi some of the older alluvial surface has been removed and redistributed downstream. South of the Motihari-Purnea line the streams, including also the Ganges, tend to flood and to deposit sediment.

It would appear, then, that the northern part of the alluvial plain is now tending to rise along with the Himalaya to the north, the southern part, up to the Ganges. is tending to sink. We will see later how this is just a part of a more general movement between the Peninsula and the Himalaya.

From a geological map of India it will be seen that the north-east corner of the Peninsula, as indicated by rock outcrops, is represented by the Rajmahal hills. These hills form a scarp on their western side, but slope away in the form of a plateau dipping below the Gangetic alluvium towards the east and also to the north. The western and southwestern side of this plateau has been dissected, indicating uplift there, whereas the eastern and northern sides, dipping flatly below the alluvium, indicate tilting and subsidence in that direction. In other words the Rajmahal hills represent a hinge zone, between uplift to the southwest and subsidence to the east and north.

If a traverse is made south from Bhagalpur or Monghyr, the Gangetic alluvium is seen to thin out quickly, and the surface of granite and metamorphic rocks rises gradually southwards. Projecting above this surface there are, however, ridges of resistant rocks, but the general character of the country is that of an old plain surface. Southwards, however, *e.g.* south of Dumka and Jhajha, signs of dissection of this old surface become noticeable, river gradients steepen, streams are cutting downwards, and the topography is much younger, eloquent of fairly recent uplift.

Further west the change is more pronounced and in Hazaribagh and Gaya districts there is an abrupt contrast between the southern thin edge of the Gangetic alluvium and the highly dissected edge of the 1,250 feet plateau stretching from Chauparan and Kodarma towards Giridih. In the east-west belt of country to the north of Kodarma the streams are rapidly cutting downwards, and although the level of the intervening ridges remains at 1,250 feet, the whole belt has been dissected in a most remarkable fashion. The

headwaters of these streams are extremely active and are rapidly cutting back into the plateau, removing the old soil surface and forming widespread bad-lands along the edge of the plateau. These bad-lands merge into the deeply dissected belt to the north.

The whole of this dissected belt is clear evidence of comparatively recent uplift. The streams and rivers dissecting this belt are carrying away an immense burden of sediment. Uplift has been in stages; alluvium deposited during earlier stages of uplift at the debouchment of the rivers has since been deeply scoured and left as high terraces and cliff faces: excellent examples of these can be seen east of Dabaur on the Kodarma—Patna road. The manner in which some of the larger streams now tend to deposit sediment immediately within their debouchment suggests that, just at present, there is a reversal of movement, subsidence, at the extreme northern edge of the belt.

Further west we find that this dissected scarp swings round to form the southeastern side of the Son Valley. But across the Son we find that there is an abrupt difference in elevation between the Kaimur plateau and the Gangetic plains to the north; the edge of the plateau is a precipitous scarp from which the streams emerge through steep gorges. The juvenile character of the plateau-edge topography contrasts strongly with the old gently undulating surface of the plateau-top and there has clearly been uplift here.

Reviewing, then, this part of the northern edge of the Peninsula, we notice a gradual easterly and northerly slope of the old land surface in the northeast corner, towards and under the alluvium. As we go west, however, the rise southward becomes more abrupt, culminating in the Kaimur scarp. It cannot be said with certainty that the uplift to the south took place anywhere along a fault, abrupt warping, increasing westward, is sufficient to explain the phenomena. Present scarp edges are not necessarily warp or fault lines—denudation may have removed these; for example the zone of differential movement on the north side of the Kaimur plateau is now below the alluvium in consequence of denudation along the edge of the plateau.

We may now turn our attention to the eastern edge of the province. Extending from the southwest corner of the Rajmahal hills towards Parasnath and the northeast corner of the Hazaribagh plateau, there is a tract of elevated country from which the surface tends to fall away to the northwest and southeast. Certain

rivers rising to the north cut through this tract and there is much scope for the investigation of their history. To the southeast the surface gradually slopes towards the Gangetic alluvium. Just east of the Bihar border, in Bengal, the Gangetic alluvium is edged by laterite and certain grits and gravels, which may be Tertiary in age. These form gently undulating low ridges, typical of an old land surface. Further west, the surface remains undulating, but rises gently and river gradients become steeper, until, eventually, the point is reached where they emerge from the eastern scarp of the Chota Nagpur plateau.

Hence, between the Bengal border and the Chota-Nagpur plateau there is a belt of country sloping east, an old land surface not far off base level, and showing some signs of uplift to the west. But in south Manbhum the surface rises rather more rapidly and we get increasing signs of recent rejuvenation of dissection, culminating in the great range, rising to 3,000 feet, which extends east from the dissected southern part of the Chota Nagpur plateau, along the border between Singhbhum and Ranchi and Manbhum. This great east-west range may be called the Dalma range after its dominant hill, Dalma, north of Jamshedpur.

Along neither the north nor the south flanks of Dalma range is there any sign of normal faulting. Geologically, however, we find that its backbone consists of a great thickness of very resistant old lavas. There may be other explanations, but the evidence would suggest that this is a residual ridge left in consequence of its resistance to denudation. On either side are easily denuded phyllites and mica-schist. Along it are sometimes found small lateritic plateaux or relatively level surfaces, usually at 2,000 feet but one occurs at 3,000 feet, indicating old land surfaces. One of the most notable features is the manner in which the Subarnarekha river cuts across the range northwest of Jamshedpur. Several explanations may be made of this, but the most probable appears to be that the Subarnarekha is a very old stream, dating back to early Tertiary times before the present land surface commenced to be sculptured. It may be noticed that where the Subarnarekha cuts across the line of the Dalma range the lavas of the range have been denuded down to the level of the mica-schist plains for a strike distance of several miles.

South from the Dalma range are the undulating plains of Singhbhum with high residual hills projecting above them. On their eastern side, along the valley of the Subarnarekha, these plains slope towards

the coastal alluvium, but here, along the Subarnarekha itself, there is clear evidence of sudden uplift to the west. Along the edge of this alluvium there are coastal or shore line deposits of Tertiary gravels, standing at 250-350 feet above sea level, indicating recent uplift of the whole area since deposition of these coastal sediments amounting to perhaps 400 feet. Immediately to the west of the Subarnarekha, west of Mosaboni mines, there is evidence of an earlier abrupt uplift of about 300 feet; south of Manpur, in Dhalbhum there are small laterite-capped plateaux standing above the Singhbhum plains, which clearly indicate this uplift. Hence the total uplift in eastern Singhbhum, since deposition of the late Tertiary gravels, is approximately 700 feet.

West from Chakradharpur and Chaibasa, the surface rises abruptly, thus continuing southwards the dissected eastern edge of the Chota Nagpur plateau in the north. Further south, this becomes a well-defined scarp on the east side of Noamundi mine and can be followed south through the Eastern States across the Mahanadi and down through Orissa.

The Chota Nagpur plateau now remains to be described. This plateau may be divided into several parts. The main plateau standing at a general elevation of 2,000 feet, may be referred to as the Ranchi plateau, a region of flat or gently undulating country, with occasional residual ridges and, in the west, small residual plateaux rising still higher to 3,000 feet. To the north, isolated from the Ranchi plateau by the Damuda valley, is the small Hazaribagh plateau. South from latitude 22° 50′, extending across south Ranchi district, and continuing south through Singhbhum into the Eastern States, is a dissected region which is really a prolongation of the Chota Nagpur plateau. This dissected region forms rugged hill country with typical mountain scenery of turbulent streams, steep hill sides and cliffs, and narrow valleys. The reason for this dissection in the south is partly because the rocks there are of a type more readily susceptible to erosion; it is possible, also, that a greater rainfall here may have helped, although on the other hand increased rainfall may have arisen from dissection and forestation.

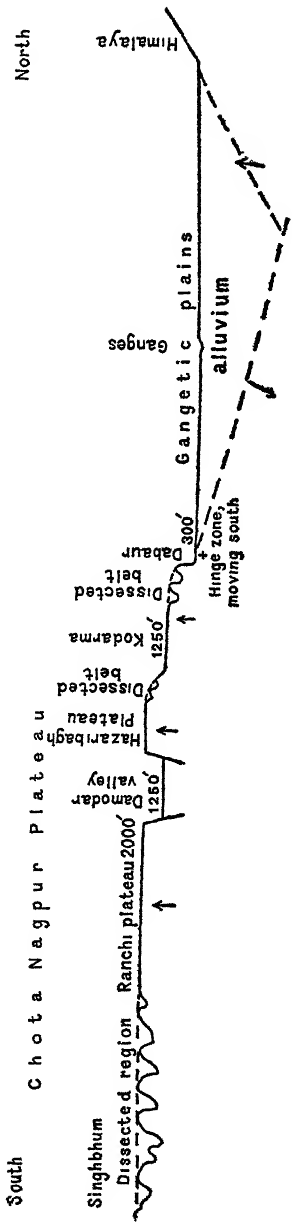
The whole plateau represents an old land surface, rising above which there are residual hills and ridges of resistant rock-masses. In the west there are several small plateaux rising a further 1,000-1,200 feet above the Chota Nagpur plateau, and representing a still older land surface which is now almost completely obliterated.

The Chota Nagpur plateau is being subjected to rapid erosion all around its edge. It is a region of uplift, the differential movement along its northern and eastern sides is approximately 800 to 1,000 feet. The Netarhat and other plateaux west of Lohardaga were formed by a still earlier general uplift of at least 1,000 feet, the older land surface being almost completely removed before the later movement took place.

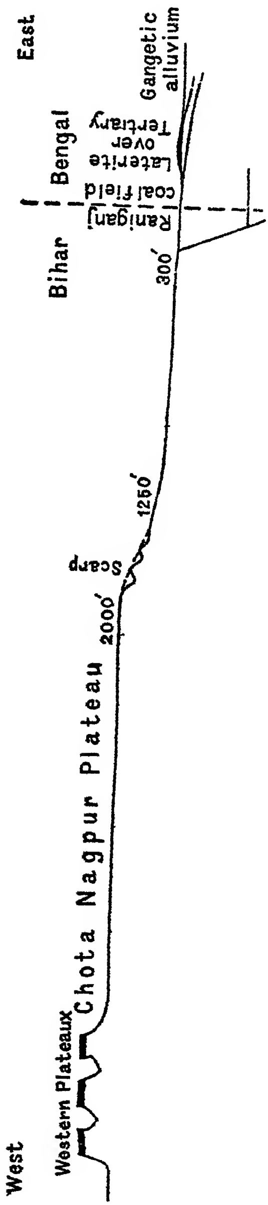
It is now possible to outline the age and extent of the successive movements which have taken place in South Bihar. Capping the Netarhat group of plateaux is a layer of Deccan traps which, however, have been largely altered to laterite. These traps are, approximately, of the same age as the Rajmahal traps which, we have already noted, tilt below the Gangetic alluvium at the northeast corner of the Peninsula. We are justified in supposing that these lavas, originally, were poured out at approximately the same level over an old pre-Tertiary peneplained land surface. So far as the eastern part of the Rajmahal hills is concerned these lavas can never have been uplifted, as they have not been subject to erosion; they may have suffered depression. The whole area, across from the Rajmahal hills to Netarhat, is indicative of uplift; the erosion of the successive plateaux could never have been formed under widespread depression. We may, therefore, accept the original level of the pre-Tertiary peneplain as being rather lower than the present level of the base of the lavas along the western scarp of the Rajmahal hills.

Subsequent to outpouring of the Deccan trap there was prolonged erosion, and uplift to the extent of about 1,000 feet in western Chota Nagpur. This uplift permitted the development of a widespread peneplain, 1,000 feet below the lavas in western Chota Nagpur, and remnants of the latter were left as small plateaux in the west. This peneplain was being formed throughout the greater part of Tertiary times.

Next, in the latter part of the Tertiary period, uplift was renewed to the extent of about 1,000 feet in western Chota Nagpur, but in the form of a block movement with sharp warping along a north-south line which is now represented by the eastern edge of the Chota Nagpur plateau. At the same time a trough developed along the valley of the Damuda, presumably due to faulting, cutting off the small Hazaribagh plateau to the north. Along the northern side of the plateau the movement was more of the nature of a tilt, the surface sloping more gradually down towards Kodarma.



(a) Section from north to south across Bihar.
(Arrows indicate direction of movement.)



(b) Section from the western plateaux to Raniganj.

FIG. 1.—Sections across Bihar.

Since this late Tertiary differential block movement, uplift of the whole western region has continued to the extent of a further 700-1,000 feet. This latter movement has given rise to a tilting of the land surface east from the edge of the Chota Nagpur plateau to the coastal alluvium, and northeast towards the Rajmahal hills; only the western side of the latter shows evidence of this final movement. In consequence of the gentle character of this final tilting there has been less tendency for vigorous erosion in the plains east of the Chota Nagpur plateau than along the edge of the plateau itself. Along the northern side, however, the tendency west of the Rajmahal hills has been towards a steepening of the tilt, culminating in the sharp warp represented by the fall in elevation from Kodarma to the plains of Gaya, and this characteristic continues across to the scarp face of the Kaimur plateau.

Stages of this final movement are represented by the small plateaux south of Manpur in southern Dhalbhum, and by the elevation of the late Tertiary coastal gravels in eastern Dhalbhum. The movement still persists in the form of a gradual rise of the whole landmass south of the Gangetic alluvium.

Examining broadly these Tertiary to Recent movements in the whole of Bihar, we note that there has been a definite subsidence to the north and northeast in the region of the Ganges. North of the Gangetic plains, there has been vast uplift in the Himalaya. To the south and southwest there have been stages of uplift totalling nearly 3,000 feet. In a northeasterly direction the hinge zone between uplift and depression has been the Rajmahal hills. In a northerly direction it has been along the southern side of the Ganges. This northern hinge zone is gradually creeping southwards, however, and there are signs that depression has set in just within the edge of the Kodarma scarp. As a parallel to this southerly creep of the hinge zone, we have seen that the tendency also is for the northern part of the Gangetic alluvium to be uplifted. Stating these tendencies more picturesquely, we may say that the uplift which gave rise to the Himalaya is tending to encroach southwards, as also is the subsidence of the Gangetic plains.

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CHAPTER III.

GEOLOGY.

To the geologist, mineral deposits are known to occur not entirely haphazardly. There is a connection between the geology of a region and the types of minerals which may be found in different parts of that region. With a knowledge of the geology, although it may not be possible to assert that certain minerals do occur in particular areas it is possible to say that certain minerals cannot possibly occur there. Frequently, one may even be in a position to advise that the geology is favourable to the occurrence of certain minerals in definite areas. A knowledge of the geology does, accordingly, narrow the area of search for particular minerals very materially.

The physiographical division of the province is related, to some extent, to the geology. In the north, the Gangetic plains are, of course, typical of alluvial country. South from these the surface rises from the plains to the Chota Nagpur plateau which, with the lower plains to the east, consists of granitic rocks with associated metamorphic and basic igneous rocks, and in which are large areas of sedimentary rocks constituting the coalfields. The southern dissected hilly part of the province is mainly of altered sedimentary rocks.

Arranged in order of age, youngest to oldest, the following are the main geological formations represented in Bihar :—

Alluvium.

Laterite.

Late Tertiary gravels.

Siwaliks.

Rajmahal and Deccan trap.

Infratrappean beds.

Gondwanas	Mahadevas, supra Panchets.	
	Panchets.	
	Damodar Series	Raniganj coal measures.
		Ironstone shales, Barren measures.
		Barakar coal measures.
	Talchirs.	

Vindhyans.
Newer Dolerites.
Kolhan Series.
Granite and related rocks.
Iron-ore Series, including other sedimentary and igneous schists of probably equivalent age. } Archean.

In the map accompanying this memoir, several of these formations have been grouped together, as merely a simple geological map is required to show the relation between mineral and rock distribution.

The Archean rocks occupy more than nine-tenths of the province south of the Gangetic alluvium. Cropping out over the remaining one-tenth are the Gondwana sediments, which constitute the coal-field basins, with, in addition, small areas of Vindhyans and Deccan traps on the west and Rajmahal traps on the east. The Archeans form a basement underlying all of these later rocks.

The general strike of the structural lines in the Archeans is normally east-west, except in Singhbhum, near the southern border of the province, where the rocks east and west of longitude 86°00 trend southeast and southwest respectively.

The Archeans may be divided into two main rock groups: (1) sedimentary rocks with which are associated both extensive lavas and intrusive basic igneous rocks, and (2) widespread granite intrusives. The latter are dominant east and west across the centre of Chota Nagpur, whilst the sedimentary and basic igneous group becomes important in northern and southern Chota Nagpur.

The northern sedimentary belt first becomes evident south of the Ganges, by ridges of quartzite and quartz-schist which project above the alluvium in Gaya and Monghyr districts. These are usually accompanied by slates and phyllites. Further south, within the dissected northern edge of the Chota Nagpur plateau, mica-schists, quartz-schists and hornblende-schists occupy a wide belt of country, but they are permeated by innumerable intrusions of granite. Over a considerable area the original granitic magma had soaked thoroughly into the mica-schists, thus giving rise to hybrid rock types. Very little detailed geological mapping has, as yet, been done in this belt and the map is here rather generalised.

Further south, rising towards the Hazaribagh plateau, occasional belts of mica-schists, quartz-schists and hornblende-schists occur,

but they diminish in area southwards and, apart from small inclusions, the whole central plateau across Ranchi district is granitic. Along the upper Damodar valley, and extending west across the Koel in Palamau, there is a belt of sediments, including crystalline limestones, in the granitic rocks.

The sedimentary group is best known, and perhaps best developed, in the southern part of the province, in south Ranchi, south Manbhum, and Singhbhum. Here, the group is known as the Iron-ore Series, and contains rocks representative of all grades from relatively unmetamorphosed to highly metamorphosed types: sandstones, conglomerates, quartzites, quartz-schists, phyllites, garnet-mica-schists, limestones, calc-schists, banded hematite-quartzites, etc. The associated basic lavas and intrusive rocks are now altered to epidiorites, hornblende-schists, biotite-schists and talc-schists. Within the Iron-ore Series, and more particularly within the banded hematite-quartzites, are the great iron-ore deposits from which the Series has derived its name.

We do not yet know what the relation is between the Iron-ore Series of southern Chota Nagpur and the schist, of Hazaribagh, Gaya, Monghyr and Santal Parganas. Both groups are older than the more widespread granite intrusives and both possess many characteristics in common; it is not improbable that the northern group may belong to the Iron-ore Series.

The great mass of granitic rock which extends across the central part of the province, and penetrates also the schists to the north and south, is known as the Chota Nagpur granite. Certain isolated areas of this granite have been given distinguishing names, *e.g.*, the Singhbhum granite extending southeast from Chaibasa into Mayurbhanj and Keonjhar, and the Chakradharpur granite-gneiss east and west of Chakradharpur. In the past, because of its peculiar mode of denudation and weathering in northern Chota Nagpur, it has been known as the Dome gneiss.

The Chota Nagpur granite is sometimes gneissic or schistose, more particularly towards its borders, and it is frequently contaminated by the absorption of included schistose material. All stages between inclusions and completely absorbed material may be seen, and the gneissic banding in the granitic rock is really a ghost structure of the trend lines in the original schists.

The granite varies from a biotite-granite to hornblende-granite. These also vary widely from fine to coarse grained and are

occasionally coarsely porphyritic, with crystals of felspar several inches across. Veins of pegmatite are commonly associated with the Chota Nagpur granite, and, where these pegmatites penetrate the mica-schists of Hazaribagh, Gaya, and Monghyr, they contain in places large crystals of mica.

It is probable that the granitic rocks of Bihar are not all of one age; there is evidence in Singhbhum that certain granitic rocks, known as granophyres and soda-granites, to which the copper deposits are related, may possibly be later than the greater mass of granites.

Originally, the whole of the sedimentary rocks of Singhbhum were grouped with the Iron-ore Series, but recently a group of sandstones, conglomerates, shales and limestones, known as the Kolhan Series, has been found to be much later in age than the Iron-ore Series proper, and later even than the Singhbhum granite. It is not yet certain whether the Kolhan Series should be classed as Archean, or grouped with rocks known as Cuddapah in other parts of the Peninsula. The actual delineation of the boundaries of the Kolhan Series has not been completed as yet, and, apart from the eastern and southern boundaries of the main Kolhan basin south of Chaibasa, the western and northwestern boundaries still remain to be separated from the Iron-ore Series.

Intrusive into the Singhbhum granite, and also into the Iron-ore Series, there is a remarkable group of basic igneous dykes, which have been called the Newer Dolerites. Their exact age is indeterminable; although perhaps of Cuddapah age it is by no means impossible that they are related even to the Deccan traps. In places they have suffered some metamorphism, but now that we are beginning to appreciate the extent of Tertiary earth movements in this part of the Peninsula, occasional metamorphism of originally deep-seated Deccan trap dykes may not be unexpected. However, they are exactly similar to another suite of dykes in Bundelkhand, Central India, which are definitely pre-Vindhyan in age.

The Vindhyan rocks are confined to a small area in the extreme western part of the province, between Sasaram and the Son river, forming the eastern end of the Kaimur plateau. They comprise sandstones, quartzites, limestones, dolomitic limestones and shales. These rocks generally are horizontal, and crop out as precipitous scarps around the edge of the Kaimur plateau. The following, according

to Auden, is the sequence of these rocks in Bihar, with average thicknesses :

Kaimur Series	Upper Kaimur sandstones	600 feet. Top not seen.
	Bijaigarh shales and quartzites	200 ,,
	Lower Kaimur sandstone	150 ,,
Semri Series	Rohtas limestone	500 feet. Base obscured.
	Kheinjua stage	Thickness not known.
	Porcellanite stage	?

The principal basins of the Gondwana rocks are distributed in an east-west belt, parallel to the general structural trend of the Archeans, and conforming approximately to the direction of the Auranga and Damodar valleys, from the Hutar coalfield in the west to the Jharia and Raniganj coalfields in the east. There are, however, other basins of Gondwanas off this main line of strike, some of which, such as Giridih, are important coalfields. The dominant rock in which the coal seams occur is sandstone, but shales are also abundant.

The following is the sequence given by Fox and Gee, of the Gondwana rocks in Bihar :—

	Raniganj field.	Jharia field.	
Panchet Series.	Hirapur stage	Not represented.	
	Maitur stage		
	Slight unconformity.		
Raniganj Series, 3,300 feet.	Kumarpur sandstones	Lohpiti sandstones	Raniganj Series, 1,840 feet.
	Nituria coal measures	Telmucha coal measures	
	Hijuli sandstones	Jamdiha sandstones	
	Sitarampur coal measures	Murilidih coal measures	
	Ethora sandstones	Mahuda sandstones	
Ironstone Shales, 1,200 feet.	Ironstone (Kulti) shales	Hariharpur carbonaceous shales.	Barren Measures, 2,080 feet.
Barakar Series, 2,100 feet.	Begunia sandstones	Petia sandstones	
	Begunia shales	Shibbabudih shales	
	Begunia seam	Sitanala seam (No. XVIII)	Barakar Series, 2,000 feet.
	Laikdih seam, etc.	XV to XIII seams, etc.	
	Damagaria seam	Muraidih (1) seam	

Unconformity in which Karharbari stage may be missing.

Talchir Series.	Talchir needle shales.
	Talchir boulder bed.

Great unconformity.

In the eastern part of the Santal Parganas the Rajmahal traps overlie the Gondwana sediments, which fringe the western edge of the lavas, but to the east the latter slope below the Gangetic alluvium. Dykes of related rocks dolerites, penetrate the coalfields sediments. Another intrusive rock, ultrabasic in composition and probably slightly earlier than the dolerites, has altered the adjacent coal to natural coke in many places.

Towards the western edge of the province, in Ranchi and Palamau districts, certain small plateaux, rising to 3,000 feet, are capped by outliers of Deccan traps which are more or less equivalent in age to the Rajmahal trap. They are normally altered to laterite at the surface, accompanied by bauxite in places.

The Siwaliks occur only at the extreme northwest boundary of the province in Champaran district, and consist of conglomerates and sand rock.

Along the eastern border of Singhbhum, forming the edge of the coastal plains, certain gravels are thought to be of late Tertiary age.

Laterite is found at various altitudes in the province, from the cappings on the 3,000 feet plateaux in western Ranchi and Palamau, down to the level of the laterites at 150 feet along the eastern side of the Rajmahal traps. Although some of the low level laterite may have been shed from the laterite which occurred at a higher level, for the most part both high and low level laterites are a special form of surface alteration of the underlying rocks. In the Rajmahal hills, laterites which occur at over 1,600 feet above sea level along the western scarp, slope gradually eastward to the level of the Gangetic plains.

The Gangetic alluvium has, in the past, been divided into two: (1) older alluvium occupying the higher ground and containing coarse gravels with often much surface *kankar*, and (2) newer alluvium, of silts and clays and fine sands. It is not at all improbable that part of the older alluvium may be of late Tertiary age.

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CHAPTER IV.

GEOLOGY IN ENGINEERING, FORESTRY, AND AGRICULTURE.

Following the general outline of the physiography, crustal movements and geology within the province, it may be considered relevant to indicate how this geological information can be applied to certain problems which may crop up from time to time.

Underground water supply.

The question often arises whether water can be obtained by sinking tube wells in certain regions. It may be said at once that tube wells are effective only in alluvial country, and that over the greater part of Bihar, south of the Gangetic plains, boring for water is inadvisable.

Tube wells consist of a number of lengths of wrought-iron tubes, varying generally from 1¼ inches to 8 inches in diameter in the case of shallower wells, but may be up to 16 inches for wells sunk to greater depths than 500 feet. Perforated sections, or strainers, along the tube tap the water-bearing sands at particular depths.

For quite shallow depths a simple type of tube well may be used, in which the bottom strainer is fitted with a mild-steel wedge-shaped point, and the tube is driven down into the water-bearing strata in a manner similar to pile driving. Fig. 2 illustrates such a simple type. For deeper wells boring equipment is necessary, and various designs of tube well equipment have come into use.

In shallow wells, where the water surface is not below 25 feet, suction pumps may suffice, but below that depth deep-well pumps are necessary. In good water-bearing strata an 8-inch tube well with 50 feet of strainer will yield 20,000 gallons of water per hour.

Tube wells may be sunk, with more or less success, almost anywhere in the plains north of the Ganges. South of the Ganges the possibility of using tube wells decreases as the alluvium becomes thinner approaching the rock outcrops to the south. Each case should be considered individually, a more precise general statement may be misleading.

No detailed record of the sequence and distribution of the sands and silts constituting the Gangetic alluvium of North Bihar, and

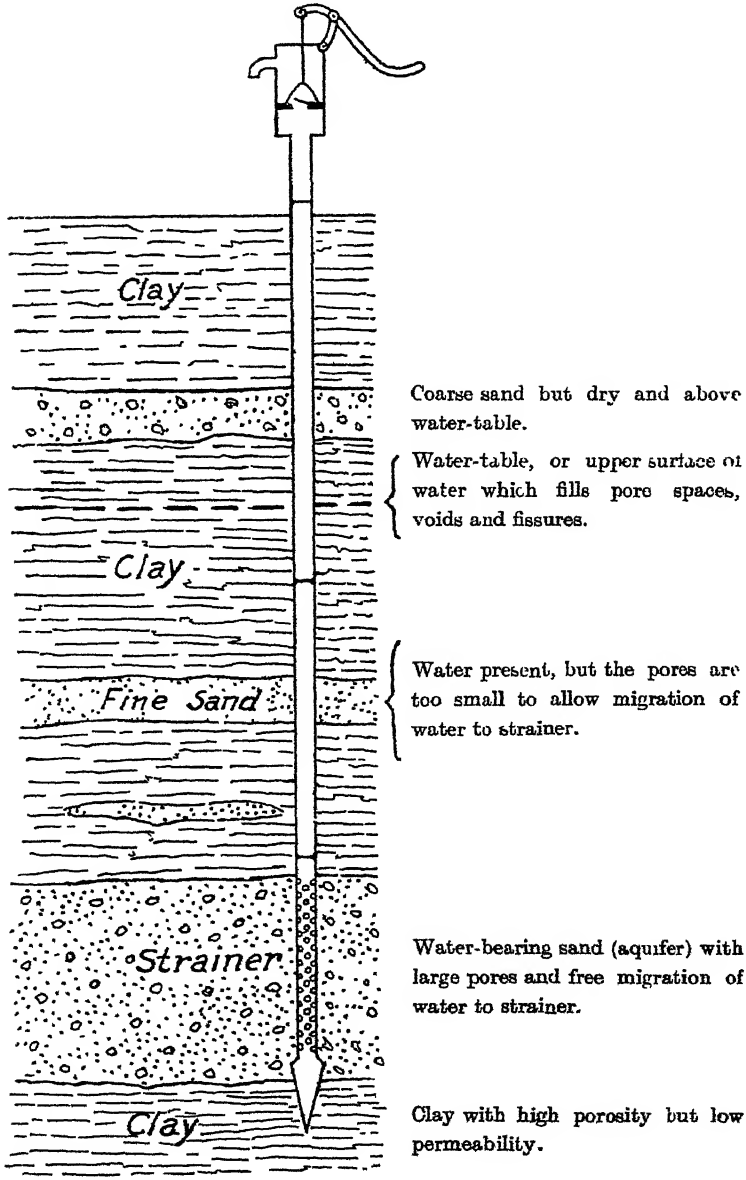

FIG. 2. Driven tube well (after J. B. Auden).

the type of water they contain, has been compiled from the logs of tube wells so far sunk. Such a compiled record is advisable and should be maintained for future wells so that eventually clear advice can be given on the depths and distribution of certain types of water within the alluvium.

Although in certain areas, particularly in Purnea district, the surface alluvium consists of a deep bed of sand, over the greater part of the Gangetic plains in Bihar a thick bed of loamy clay is at the surface. Infiltration of rain-water through this clay layer to the sands below must be negligible; the sands obtain their water supply either from areas where they reach the surface, or from rivers the sand beds of which may be deeper than the surface clay and may make direct contact with the underlying sands. It is apparent that over the greater part of the Gangetic plains the intake of the deep-seated water-bearing strata is not the immediate surface, but is closer to the edge of the alluvium, and much of the water has travelled underground from as far afield as the United Provinces and the Punjab.

There is evidence that at depths below 200 feet the water-bearing strata are under sub-artesian conditions. It is by no means improbable that, at much greater depths than have yet been reached in Bihar, artesian conditions exist which would give rise to a flow of water at the surface. In a borehole at Lucknow in 1890 water flowed out at the surface from a bed at 1,200 feet. During and for some hours following the 1934 earthquake, water gushed out at the surface over a wide area of country, in many cases to a height of several feet. The water apparently came from a great depth, and the phenomenon suggests artesian conditions.

The use of underground waters in northern Bihar is in its infancy, but even at this early date the control of all tube wells should be placed advisedly under one authority. The ultimate flow of water that can be obtained from the deep-seated sands is determined not by the number of tube wells put down, but by the slow rate of underground percolation over the whole area. This rate cannot be increased above a certain maximum. At present tube wells are required by the Public Health Department, the Agricultural Department, and by private interests. The latter cannot be permitted to put down an indefinite number of tube wells. The underground water supply is public property, in so far as it is an asset of the province as a whole, and every tube well is making use

of percolation from many miles around. Excessive extraction of water from many tube wells in limited areas may lead to comparative local exhaustion of supply. It would be advisable to institute a system of licensing early in the history of deep tube wells in Bihar, thus ensuring complete control in the future. In particular, attention should be paid to a judicious spacing of wells.

South of the Gangetic alluvium, only normal wide diameter wells are recommended. There may be a few isolated instances in which local deep alluvium, or a very deep capping of porous decomposed material granite, would permit the successful use of tube wells, but their location would be fortuitous. It is possible also that wide-diameter boreholes may. occasionally, be so fortunately placed in rock that they yield a good supply of water, but the chances against this are enormous. They have a slightly greater chance of success on the coalfields, and the western part of the Rajmahal hills, where they may penetrate into flat-lying Gondwana sediments which may carry water along innumerable joints and faults. In the schists and gneisses, unless a borehole happened to enter some such structural feature as a porous shear zone or fault, it would be almost completely dry. In view of the cost of boring and the very slight chance of success it is not to be recommended.

On the coalfields wide-diameter wells may be sunk not only in the surface soil cap but also in the sedimentary rocks with fair chance of success. On the granitic rocks, once the well has been sunk through the surface cap of soil and decomposed rock, there is normally little chance of obtaining water in the solid rock below, unless this happens to be closely fissured. In the schists, chances of success of wells vary according to the type of rock penetrated.

The water table in the granitic rocks follows the surface topography, but surface valleys and ridges tend to be flattened out in the underlying water table. In other words the water table is met with at a greater depth below surface on ridges than in valleys—it may even reach the surface in the latter. The depth to which the surface soil and decomposed rock extends is extremely variable. In seeking well-sites, thickness of soil cap and direction of drainage are a guide to some extent. Where such resistant features as a basic dyke, or a quartz vein, or possibly even a fault, may hold up the flow of sub-soil water, there, a good well-site may be sometimes located. Such a site, along the bank of a stream where there is a good depth of sand, is frequently ideal, and may yield an excellent

quantity of water. Where, however, very large quantities of water are required then it is advisable to drive a gallery from the bottom of the well into the sands of the river bed.

The above points may serve merely as an indication of the difficulties in approaching questions of underground water supply. The engineer is well advised, however, not to attempt to apply the general principles himself. Each case must be considered on its own merits by a geologist familiar with questions of water supply.

Reservoirs and dam sites.

The storage of bodies of water for irrigation and other purposes is one of the oldest engineering features of India. These storages vary from small simple village tanks (used frequently for irrigation as well as for drinking and washing purposes) to large reservoirs with masonry or concrete dams. In the future, as the population increasingly segregates into large town centres, it will become necessary to find storage for water supply to these towns.

Bihar has the advantage of a plentiful rainfall and excellent reservoir sites distributed widely over the southern half of the province. It is particularly desirable, however, that a detailed survey of the water-storage possibilities of the whole province should be carefully made. Water-storage in Bihar is required not only by the local Government but also by the Bengal Government. The latter has in view sites not only along the Mor river west of Suri but as far afield as the Barakar river south of Kodarma. Indiscriminate allotment of water-storage to each province without anticipating the general requirements of distribution in the future will eventually lead to difficult and perhaps grave problems. Even the water supply for Bihar itself requires careful consideration as to which sites should be reserved for irrigation, for town supply or for railway purposes. A definite plan of water conservation for the future has now become advisable. The institution of such an enquiry does not mean that expensive engineering projects will be involved. All that is required is for a thorough expert examination to be made of all the water-storage sites within the province and a plan to be drawn up of their allocation for definite purposes in the future.

This is not the place to enumerate the water-storage sites within the province; too many factors of a technical character are involved which require the close cooperation of engineer and geologist. Rivers

cutting across residual ridges provide many sites. Rivers descending from plateau scarps may even provide hydro-electric possibilities. In the examination of a reservoir project, apart from the water-tightness of the reservoir basin itself the main concern of the geologist is the dam foundation and the materials to be used in its construction. Frequently, the reservoir basin may be suitable but the site on which the dam is to be founded may possess weaknesses. Such weaknesses may even mean that the project must be abandoned, but sometimes it may be possible to design the structure to avoid the weakness, or it may be possible to choose an alternative site. Occasionally it may be necessary to carry the foundations down to such a depth that the whole project becomes economically impracticable.

For dam construction there is scarcely a site in South Bihar where suitable materials are not to be found close at hand.

Railway alignments.

There have been instances, in Bihar, of railway alignments being chosen along which water supply difficulties were encountered after construction. Alternative alignments may have been possible along which water supply would be ample. In the preliminary survey work for railway alignments the geological aspect should always be kept in mind and advice sought on water supply, bridge foundations, safety of cuttings and tunnels, and the supply of building materials. No detailed advice can be given here, but it may be insisted that engineers should make use of the geological knowledge available in the province.

Road alignments.

The choice of alignment of roads in such an area as South Bihar is often partly determined by the best sites available for bridges at river crossings. No detailed advice can be given, but here again geological opinion should be sought. In steep hill country geological advice may lead to the avoidance of sections susceptible to landslips. The availability of suitable road metals close to the road is also important.

Earthquake areas.

North Bihar is an area liable to disastrous earthquake shocks, and, as a consequence, susceptible to severe damage. The great

Bihar-Nepal earthquake of 1934 has shown how widespread that damage can be.

In describing the physiographical development of Bihar, in Chapter II, it was noted that a severely contrasted movement is in progress between the rising Himalaya to the north and the depressed northern edge of the Peninsula below the Gangetic alluvium, the latter movement being also connected with the uplift of the Peninsula further south. This sharply contrasted movement occurs along a line which follows the outer rim of the Himalaya, from Motihari through Sitamarhi, Madhubani, and towards Purnea. Periodic sudden relief to the strain set up by the movement manifests itself in occasional earthquakes. The unconsolidated nature of the great depth of alluvium which covers the crust in this region does not tend to minimise in any way the severity of such shocks, which cause the whole surface to move both laterally and vertically, destroying anything erected upon it.

Perhaps the simplest picture of what happens in this region during an earthquake is as follows:

Pour into a large tin box a deep layer of sand, and mould this into depressions to represent rivers, lakes, tanks, and ditches, and elevations to represent railway and road embankments, river and field bunds and village sites. Then give the sand a severe shaking. The tendency will be for the depressions to become infilled by sand rising from the bottom and by their sides moving inwards, in consequence of the sand spreading laterally from the elevations. If the sand is moist it will be found that cracks will form and that lateral movement towards depressions will tend to be from such cracks.

If a heavy block of stone is placed on the sand it will be found after movement that the block has sunk into the sand a little and is perhaps tilted. If two blocks lightly joined together are placed on the sand, after movement they will be found to have subsided differentially with perhaps fracture of the joint.

And so we find, after a severe earthquake in this region, that river and lake banks and tank edges move inwards a few feet, and the bottoms of the depressions tend to rise. Road and railway embankments tend to subside and may even sink level with the surrounding country. River bunds subside and may permit the streams to break through their banks. The surface is traversed by innumerable cracks which are often parallel to the banks of rivers and lakes or other depressions, or are concentric to heavy structures.

Structures built on or close to the banks of depressions are completely destroyed mainly because of actual spreading of their foundations by lateral movement. Heavy large buildings, particularly those of two or more storeys, are often traversed by large cracks as a result of unequal vertical movement of the foundations beneath the heavy structures. Bridges are destroyed by inward movement of the abutments and lateral movement of the piers. No substantial structures in the vicinity of depressions can withstand these surface movements. Further away, on level ground without adjacent topographical features, even a light building may still be damaged by shaking, and if not well built, and particularly if the structure is tall, it may be destroyed by actual tumbling.

It is apparent that buildings should, as much as possible in North Bihar. be kept away from the vicinity of surface depressions. Heavy two-storey structures should be avoided, and the foundation of each building should form a well-tied single unit. Roofs should be kept as light as possible as the inertia of a heavy roof during an earthquake tends to destroy the walls. The use of *kutcha-pucca* brickwork should be avoided, particularly in two-storey buildings. Fragile ornamentation, such as balustrades and projecting gargoyles and other excrescences, should be left out of the design of buildings, as they fall away during an earthquake and cause loss of life.

In constructing railway and road embankments the material should, if possible, not be taken from borrowpits alongside the embankments; such pits tend to accentuate the elevation and permit the readier sinking of the embankments during earthquakes. For road bridges the all-steel screw-pile type is preferable as, although it becomes twisted, it is often negotiable after an earthquake and much of it can be salvaged. For heavier railway girder bridges, no design can possibly withstand a severe earthquake.

In congested bazar areas, roads and lanes should be made as wide as possible so that they may not be blocked by tumbling debris; this is particularly necessary where tall buildings are customary. The retention of open spaces within bazar areas will help to reduce loss of life.

It is becoming apparent that certain zones in North Bihar are more susceptible to the effects of earthquakes than are adjacent zones. As yet, however, our record of the distribution of earthquake damage in successive shocks is insufficient to permit any precise statements to be made. If the information were sufficiently

reliable it would be possible to avoid the more susceptible zones in determining the sites of future civil headquarters or large manufacturing centres. For the present, the distribution of damage during the 1934 earthquake may be taken as a reasonable guide. A detailed record of this damage may be found in Memoirs of the Geological Survey of India, vol. 73.

The study of the means by which earthquake effects may be reduced to a minimum is almost a subject in itself, and requires the cooperation of engineer and geologist. For Bihar, a summary of the point of view of the geologist has been provided by Dunn in the above-quoted memoir.

Soils.

From the point of view of origin, soils are of two types: (*a*) those consisting of material which has been transported from some distance, and (*b*) those formed by the alteration of the immediately underlying rocks. The former occur along the bottom of river valleys, the latter type (known as residual soils) are found on elevated tracts, hills and plateaux.

The valley sediments will consist of a mixture of all the material brought down by the streams from the rocks of the watershed, although there may, of course, be some tendency for sorting of these sediments according to grain size and specific gravity. With the admixture of sandy material from sandstones, quartzites and granites, with clayey material from shales, phyllites and lavas, the tendency along the valley bottom is to the accumulation of light loamy soils. In such cases, however, where the streams traverse only siliceous rocks or rocks which provide a clay soil, there the sediments can only be sands or clays respectively. Over the greater part of Chota Nagpur the streams are draining granitic rocks, so that the sediments are mainly sandy. Clayey silts do increase in the lower reaches, however, in consequence of sorting. In North Bihar the surface sediments usually form a loamy clay, with occasional stiff clays, but over wide areas, particularly across the Kosi river and over Purnea district, there are extensive beds of fine sand. In northern Purnea the surface is widely covered with an unconsolidated conglomerate of coarse pebbles.

Away from the valleys the soil forms merely a cap of varying thickness, and results from alteration of the rocks below, so that the nature of the soil will depend on those rocks. The granite which is so

widespread in the central and southern part of Bihar, gives rise to a rather coarse sandy soil with just sufficient clay to hold it together. On the plateau country this granite soil frequently contains a certain amount of iron hydroxide, which causes the soil in the dry season to set almost as hard as cement at the immediate surface. Such soils are not particularly fertile as a rule. They are frequently known as "red soils" and represent a very old soil surface.

Over the mica-schists, which occur as patches of variable extent in the granite area, the soil cap is much more argillaceous. Owing to the ease with which these schists are eroded the mica-schist tracts are often deeply incised by small streams and the soil cap is much more rapidly removed and is thinner than over the granite.

As a rule quartzites and quartz-schists do not form widespread outcrops, but usually project as elongated ridges. There is little or no soil cap on these ridges, but along their flanks the soil shed from them may be very sandy.

The hilly country of southern Chota Nagpur, including Singhbhum, south Ranchi and south Manbhum, provides, perhaps, the most variable soil caps. Here, outcrops of granite, mica-schists, quartzites, phyllites, lavas, limestones and other rocks rapidly alternate. The granites and quartzites give rise to sandy soils; the mica-schists and phyllites to loams varying to clay soils; the lavas to heavy clay soils; whilst the small outcrops of limestone will give rise to calcareous soils. Sometimes these soil caps are sharply defined, and in places give rise to remarkable contrasts in vegetation. The author has occasionally found it possible, for example, to map areas of phyllites within lavas by the clumps of bamboo jungle which grow on the phyllites and which stop exactly on their boundary. In other cases, the sal trees over ultrabasic igneous rocks burst into fresh leaf later than over adjacent phyllites. Sal jungle is found to be better developed over some rocks than over others, but in noting all the various relations between soil and vegetation aspect must also be taken into consideration.

Over the Vindhyan rocks of the Kaimur plateau the soils are usually sandy to light loams in consequence of the preponderance of sandstones. It is remarkable how frequently *kankar* is found in these soils; one explanation may be that it represents calcareous matter from limestones since removed by denudation. Jungle is usually sparse and bushy on this plateau.

In the coalfields the soils are, as a rule, rather heavy loams. The rocks are alternating shales and sandstones, but the latter usually contain a considerable proportion of felspathic grains which weather to kaolin. On the whole the flatter, low-lying coalfield country is more widely covered with re-distributed surface capping than are the highlands.

The Rajmahal and Deccan traps give rise to a stiff clay soil where they have not been altered to laterite. For the most part, however, these traps form plateaux, over which the special form of surface alteration known as *lateritisation* takes place.

The formation of laterite is described in Chapter XII, but, briefly, it may be said that, in a climate of alternating prolonged wet and dry seasons, where the drainage is suitable the tendency is to the chemical accumulation of alumina and ferric hydroxide at the surface and the removal of silica in solution. Any rock, provided that it contains some alumina and iron, can give rise ultimately to a capping of laterite, but this capping will form far more readily over rocks or sediments high in alumina and iron, such as over traps and shales.

Lateritic caps are frequently only a few inches thick, although they may vary up to many feet. In consequence of their dense, fine-grained and colloidal nature, with high iron content, they are useless for agricultural purposes and permit only a very sparse and poorly developed jungle growth.

The red soils of the Chota Nagpur plateau are an incipient stage in the formation of laterite. Their peculiarity arises from the accumulation of iron in them over a very prolonged period of alteration of the underlying granite, the iron content of which is not noticeably high.

Finally, the late Tertiary sediments at the eastern border of Singhbhum are comparable to the more recent accumulations of alluvium. They have, however, been exposed to sub-aerial conditions over quite a considerable period, and have been readily susceptible to chemical alteration at the surface, with the formation of laterite. These laterites form often a continuous sheet extending into Bengal on the higher ground along the edge of the Gangetic and coastal alluvium.

The above broad outline of soil distribution merely serves to indicate the importance of a knowledge of the rocks in Bihar to both forestry and agriculture. It is based only on the relative silica-

clay composition of the soils, but other constituents are of great significance, and of these lime is one of the more important, for it is found as *kankar* scattered on the soils over the greater part of the province. Even when the underlying rocks or sub-soils contain the minimum amount of calcium, that amount becomes concentrated at the surface under the climatic conditions of this area. Other important soil constituents include potash, phosphates, manganese, etc., all of which are contributed by the underlying rocks, whilst organic material, such as carbon and nitrates and other salts derived from organic acids, have been made possible by vegetable and animal life. The distribution of these in various zones of the surface soil provides scope for an immense study in Bihar. In agriculture, a study of soil is of importance not only from the point of view of crops, but also of animal life, for deficiency or excess of certain constituents may give rise to diseases.

A thorough soil survey of Bihar is becoming a necessity. That survey must be based on the geology of the province for, apart from a few of the organic acids, carbon, and bacteria, the soil derives the whole of its constituents from the rocks.

Soil erosion.

In Chapter II the sequence of uplifts which has given rise to the plateaux of Chota Nagpur is outlined. It will have been gathered that one effect of these uplifts has been the rejuvenation of stream activity, and this activity is particularly prevalent along the edges of the plateaux, where the rocks and surface soils are being rapidly eroded.

Nature's demands—the erosion of the surface in an area of steepened gradients—cannot be denied, but they can be slowed down to some extent. The most rapid erosion in such an area is in the early stages, when the headwaters of the streams are beginning to remove the old soil cap. Once this cap is removed the eroding action of the streams on the underlying rocks is much slower.

Along the edges of the plateaux, particularly in the Hazaribagh district where the headwaters of the steep streams are cutting deep into the scarps, the soil cap over wide areas is intersected by innumerable gullies which are forming " bad lands ". A very considerable amount of fertile paddy land is, in this way, being destroyed. Once this type of erosion has commenced it can be slowed down by

encouraging suitable vegetation to grow, both trees and grasses. But even this will reduce lateral erosion for only a very short time, unless vertical erosion along the main drainage channels can be reduced by local checking of the streams to flatter gradients. This checking can be accomplished by means of a system of weirs along each stream. In many places the stream gradient is checked by natural barriers before lateral erosion has completely removed the soil cap: in such cases the lowered soil surface may be as fertile as the soil removed and can be planted with vegetation to prevent further erosion. In the centre of the plateaux there are numerous places where the removal of a barrier has been followed by a temporary renewal of erosion and removal of a layer of soil from the surface, until the streams again assume a flatter gradient, but the lowered surface is usually just as fertile. For the most part, the checking of erosion in the centre of the plateaux is not of urgent importance.

The critical zones of erosion from the point of view of agriculture are along the edges of the plateaux. One of the most serious is that extending from Chauparan, through Kodarma and into Giridih subdivision. For belts such as this there is no alternative but to abandon large tracts as agricultural areas and to form zones of intensive afforestation.

In the highly dissected region of south Ranchi and Singhbhum, representing the southern extension of the Chota Nagpur plateau, the problem is entirely different; it is not a question of the prevention of destruction of flat agricultural lands but of erosion of soil from jungle-covered steep hill slopes. Here erosion commences from radial drainage lines which cut straight down the hill sides, exposing the underlying rocks and then spreading laterally. The object here must be to prevent the formation of these radial gullies, or, if formed, to break them up. Prevention is best done by contour ridging which leads the drainage waters by gentle gradients to streams along which erosion can be controlled. In this way rapid local erosion can be quickly checked, and is converted to a gradual and more natural lowering of the soil surface of the whole hillside, permitting the concomitant formation of soil from the underlying rocks. Once erosion gullies have been formed their further development can be checked only by breaking up the gradient with a series of weirs and barriers and by re-planting.

In hill country soil erosion is aggravated by over-grazing and deforestation which remove the protective cover from the surface

and leaves the soil susceptible to widespread removal or "sheet erosion," which may become noticeable only when the underlying rock is exposed. In flat country, however, over-grazing and opening up of the soil by agriculture may be the sole determining factors in erosion of some areas, and, even in the absence of heavy rainfall and stream activity, may permit the complete removal of the surface soil by wind erosion.

Soil erosion has become a serious problem in Bihar. It has raised questions of grave importance not only to the agriculturist and forester, but also to the engineer who has to minimise siltation of reservoirs, river channels, and canals. There is apparently some confusion of thought and lack of appreciation of what is in some cases inexorable, in others preventable, or in others unimportant. In some cases afforestation will provide a cure, in others engineering means must be used as a prevention. A prolonged and careful study is essential throughout the whole province, but it must be accompanied by a thorough appreciation of the forces of nature which are ultimately responsible for most erosion—crustal uplift.

CHAPTER V.

LOCALISATION OF MINERALS, AND PROSPECTING.

Geological distribution.

It will have been gathered from the geological account of Bihar, Chapter III, that certain mineral deposits are related to particular rock types. In the following list the mineral deposits are grouped according to the geological formations which they have been found to accompany in the province. Minerals in brackets occur in Bihar as deposits of only very minor importance and unlikely to afford a valuable industry, whilst those in italics are occurrences of purely academic interest.

Archean sedimentary rocks.—Iron-ore, manganese-ore, limestone, dolomite, kyanite, refractory quartzite, steatite (pot-stone), chert, quartzite, slate and other building stones, china-clay, ochres, [graphite, garnet, *topaz*, *corundum*, *aluminium sulphate*].

Archean basic igneous rocks,—Chromite, steatite (pot-stone), vanadium-bearing iron-ore, [asbestos, magnesite, magnetite].

Granite.— China-clay, building stones, road metal.

Pegmatite veins.—Mica, felspar, [beryl, rose quartz, *apatite*, *columbite-tantalite*, *cassiterite*, *monazite*, *pitchblende*, *tourmaline*, *triplite*].

Other veins in Archeans.—Copper, apatite-magnetite, gold, barytes, quartz, [*wolfram*, *lead*].

Kolhan series.—Building stones, iron-ore, manganese-ore, limestone.

Newer dolerite.—Road metal, railway ballast.

Vindhyan system.—Limestone, sandstone, shale, glass-sand, pyrite, [*alum shale*, *iron sulphate*].

Gondwana system.—Coal, fireclay, china-clay, sandstone, glass-sand, [iron-ore, shale, limestone, fuller's earth].

Traps.—Road metal, building stone, [agate, amethyst, opal].

Siwaliks.—[sandstone].

Tertiary.—Gravel, ballast for railways and concrete.

Laterite.—Building stone, bauxite, lithomarge, iron-ore, manganese-ore.

Gangetic alluvium.—Kankar, saltpetre, sodium sulphate, reh.

Recent alluvium.—Brick and pottery clays, sand, kankar, earths for cement manufacture, iron-ore, manganese-ore, [gold, *platinum*].

It may be remarked that the greatest or most diverse assemblage of minerals occurs within the sedimentary rocks of the Archeans. These minerals occur not only as bedded deposits, but also in definite veins which traverse the sedimentary rocks. In the Iron-ore Series of Singhbhum there are remarkably extensive and rich deposits of iron-ore, and useful deposits of manganese have also been found in these rocks. In recent years deposits of kyanite-rock from the mica-schists of the Iron-ore Series have become of great value overseas for use as a refractory material. Quartz-schists and quartzites are quarried in parts of Singhbhum by Tata Iron and Steel Co. to line the Bessemer converters at the steel works. Local phyllites and sandstones have been altered by neighbouring granites to form china-clay. Within the Chota Nagpur granite there are many inclusions of Archean sediments, varying in size; a belt containing limestones extends from Ramgarh to south-west of Daltonganj, and several of these are now being quarried for lime and cement manufacture. Ochres formed by alteration of certain rocks of the Iron-ore Series find a local use as colour wash for huts in many parts of Bihar. Chert is commonly found in the Iron-ore Series in Singhbhum and pebbles shed along the streams may find a use in grinding mills. Although garnets often occur in noticeable concentrations in southeast Chota Nagpur, there is, apparently, no market for them now as abrasives. Topaz and corundum are mainly of mineral interest, accompanying some of the kyanite-rocks.

Chromite and asbestos are exclusively associated with the basic igneous rocks of Archean age in Bihar, as also are the only known occurrences of vanadium-bearing titaniferous iron-ores, and most of the steatite deposits.

Only those pegmatites which traverse the mica-schists and which contain mica have, as yet, been of economic importance. The minerals listed in italics within brackets have been mainly mineralogical curiosities, of which, except for very small deposits of cassiterite and triplite, there have been no exploitable concentrations found to date. It is possible that certain veins sufficiently high in pure orthoclase felspar may yet be worked for ceramic purposes. Beautiful rose quartz occurs in some of the pegmatites, and it should be possible to use this for ornamental purposes.

The copper lodes of Singhbhum occur mainly within the Iron-ore Series, but some are within the adjacent granite, as, for example, the lodes at Mushabani. The apatite-magnetite veins occur in close association with the copper lodes; sometimes they are rich in apatite to the exclusion of magnetite and have been mined for use as calcium phosphate, at other times they consist of almost pure magnetite and have been mined in the past as iron-ore. Gold is known to occur associated with quartz veins in several parts of Chota Nagpur, but only in rare instances are these veins sufficiently large or of sufficiently payable grade to attract even a small syndicate or company. Veins of barytes have been found in Singhbhum, Ranchi, and Manbhum districts but, apart from the small Singhbhum occurrence, have not proved sufficiently attractive to mine as yet. Numerous large veins of pure quartz occur in the granite of Chota Nagpur, particularly in Singhbhum, and these ultimately may find a use for ceramic or other purposes.

Close to the iron-ore deposits of the Iron-ore Series the basal conglomerates of the Kolhan Series are sometimes so rich in iron from pebbles and matrix of hematite shed from the deposits, that the conglomerates too are rich enough to be mined as iron-ore. Jhiling Buru, near Gua, is an example of such a deposit. For the most part the manganese-ores of Singhbhum occur in the Iron-ore Series, but near Chaibasa the limestone near the base of the Kolhan Series has been replaced by manganese. The limestones within the Kolhan Series have been found to be too impure to be used either in iron-smelting or for cement. The basal sandstone is used locally as an excellent building stone.

In the Vindhyans, the limestones close to the Son River at Rohtas are extremely valuable for cement making, for which purpose the adjacent shales are also used. Vindhyan sandstones have been quarried widely for building purposes.

The coal-seams and fireclays of Bihar are all found in the Barakar and Raniganj stages of the Gondwana system. The china-clay which is washed from felspathic sandstones in the Rajmahal Hills is doubtfully of Gondwana age, it may be slightly younger. Some of these sandstones may, eventually, be found useful as glass sands.

The Siwaliks in the northeastern corner of the province are normally very soft sandstones or sand-rock. Little is known about

this particular area of Siwaliks, but it is unlikely that good building stones or glass-sands are available.

The late Tertiary conglomerates in eastern Singhbhum have been quarried for many years as railway ballast.

Bauxite is confined to the high level laterite, whilst normally only the low level laterite is used for building purposes. White lithomarges or clays are sometimes found immediately below laterite. Many of the iron-ores in the Iron-ore Series have become lateritised at the surface and, if the composition is suitable, these are mined as iron-ore. Surface deposits of manganese-ore over Iron-ore Series rocks are lateritic, but these may merge downwards into segregations and veins of manganese-ore.

Alluvial deposits here include not only river clays and sands but also surface soils and detrital material shed down hill-slopes. Amongst the latter, in the vicinity of the iron-ores of Singhbhum, are thick accumulations of iron-ore debris which are worked for their iron-ore content. Occasional small deposits of manganese-ore debris occur in a similar manner. Gold is occasionally found in stream sands, but in very small amounts rarely providing more than two annas per day to the villagers who wash these sands.

Geographical distribution.

It may be of interest to indicate the extent to which our geological knowledge can serve as a guide to the areal distribution of minerals, and thus restrict the area of search for individual mineral deposits.

In North Bihar, north of the Ganges, the alluvium has completely blanketed older rocks, and here we may expect to find only such materials as *kankar*, saltpetre, sodium sulphate, *reh*, sands and brick-clays.

In Central and South Bihar, the structure of the rocks trends east-west and the main mineral deposits are found to be arranged broadly in parallel zones.

Some 60 miles south of the Ganges there is an east-west belt within which most of the mica deposits occur. Smaller deposits are found outside of this belt, but are relatively unimportant compared with those within the area extending from the Kodarma forest to Gawan.

Further south is the zone of coalfields extending from the Raniganj field in the east to the Hutar field in the west. Smaller coalfields, of which the largest is Giridih, occur to the north, somewhat off the main line of Gondwana basins. Most of the refractory clays are also found within these basins.

Striking parallel with and in the close vicinity of the line of coalfields, a belt of limestone deposits of Archean age extends from near Ramgarh to the western side of the Koel river southwest of Daltonganj. Off this belt, to the northwest, limestone deposits of a different age, Vindhyan, occur on the edge of the Kaimur plateau near the Son river.

Still further south, but confined to the western part of the province, west of Lohardaga, are bauxite deposits associated with the small laterite-capped plateaux.

At the southern end of the province is the rich mineral district of Singhbhum, with its S.E.-N.W. belt containing closely associated kyanite-rocks, apatite-magnetite veins and copper lodes, in the northern and eastern part of the district. This belt is some 80 miles long and up to 3 miles in width but narrowing down to a few hundred yards in places; as a general rule kyanite-rocks occur on the northern side of the belt, then apatite-magnetite veins, and copper veins on the southern margin.

A little to the south of the copper belt, but confined to central Singhbhum, are the chromite deposits west of Chaibasa. In eastern Singhbhum titaniferous magnetite deposits occupy a similar relative position to the chromite deposits and are associated with identical rock-types.

In the southern part of Singhbhum are the kaolin deposits associated with granite, and the iron-ore and manganese-deposits in the southwest corner.

Of the remaining principal minerals which occur within the province, gold is widely but very sparsely distributed along streams, but is mainly confined to southern Chota Nagpur—Singhbhum, southern Manbhum and Ranchi. Gold-bearing veins are known only in these last mentioned areas. Building stones, such as sandstones and slates, occur at various places where Archean sedimentary rocks and Vindhyans crop out. Asbestos has so far been worked only in Singhbhum, but it may occur where Archean basic igneous rocks are found. Barytes is known in Singhbhum, Ranchi and Manbhum, but its occurrence elsewhere is not impossible. Glass-sands are

found associated with the Gondwana rocks in the Rajmahal hills, but clean alluvial sands or fine friable sandstones of any age in many parts of the province may be examined for glass manufacture. Mineral waters are widely distributed but most are found in Central Bihar, in Santal Parganas, Hazaribagh, Gaya and Monghyr districts. Ochres are found mostly in Singhbhum, Ranchi and Manbhum in areas of Archean sedimentary and basic igneous rocks, and in the Upper Gondwanas of the coalfields, but few are of good quality. Quartzites and quartz-schists are widely distributed, but those deposits from which costs of transport are low are preferred—the same remark applies to road metal and railway ballast. Steatite is widely distributed within the Archean sedimentary and basic igneous rocks, but the best material is in Hazaribagh and Singhbhum districts.

A few observations as to where certain minerals cannot occur may be relevant. Apart from the minerals already noted as occurring with the alluvium, no other minerals can possibly be found in the region north of the Ganges. It is, of course, obvious that no coal may be expected outside of the basins of Gondwana rocks. Across the broad zone of the Chota Nagpur granite no large deposit of iron-ore and manganese-ore may be expected. It is not likely that bauxite will be found outside of the high level plateaux of western Chota Nagpur. No chromite or asbestos need be expected away from the vicinity of ultrabasic igneous rocks. Kyanite cannot possibly occur in any rocks other than the highly metamorphosed mica-schists of the Archeans. Pegmatites may be expected to contain mica only where they occur in the strips of mica-schist associated with the Chota Nagpur granite.

Future search for minerals.

The foregoing account of the distribution of minerals should help in narrowing down the area of search, in future, for particular minerals in the province. From the point of view of the prospector, however, other factors have to be considered, and the most important of these is the possibility of marketing his discoveries. He should know the minerals for which there is a demand, and those for which he can expect to find no market. He may also wish to have assessed for him the possibilities of finding valuable deposits in the province.

The geology of Bihar, south of the Ganges, is rather well known but only certain selected areas have, as yet, been mapped in great detail. These areas include Singhbhum, with adjacent parts of southern Manbhum and southern Ranchi, some of the Gondwana coalfields, the Kaimur plateau, the Rajmahal hills, and a portion of the mica belt in Hazaribagh and Gaya districts. Over the rest of the province our geological knowledge is only of a general kind. Nevertheless, it is sufficiently understood for the definite statement to be made that the larger and more important mineral deposits of Bihar are now known.

Apatite.—Although, at present, there is only a very small and occasional market for the phosphate, apatite, there is scope for research on the utilisation of this mineral. The deposits known to occur in Singhbhum have, so far, only been worked at the surface. Until a definite market is found for this mineral prospecting for further deposits is unlikely to be undertaken, but it is improbable that deposits will be found outside of Singhbhum.

Asbestos.—A few small asbestos deposits have been worked in Singhbhum. The prospects of finding additional deposits, either in Singhbhum or in other parts of the province, are negligible.

Barytes.—The development of a considerable barytes industry in Bihar appears improbable. It should, however, be possible to utilise the known barytes deposits in a small way, but there appears little chance of further large veins being found.

Bauxite.—The bauxite deposits are well known, and it may be left to the companies taking them up to prospect and develop them in order to determine the reserves available. In the future there should be a good market for high-grade bauxite. Deposits in places more accessible than western Ranchi are unlikely to be found.

Chromite.—A market is always likely to be available for deposits of chromite. Sufficient is known of the geology of Bihar, however, for the inference to be made that workable chromite deposits are unlikely to be found outside of Singhbhum. There is little question that small deposits of this mineral will continue to be opened up for some time to come in the vicinity of the ultrabasic igneous rocks west of Chaibasa. Outcrops of ultrabasic igneous rocks should always be closely examined for chromite in mapping new areas.

Clays.—The fireclay deposits may be left to the refractory and pottery industries to develop, as the distribution of these deposits

is rather well known. There always will be a market for fireclay. China-clay, also, if of good quality, will find a ready sale at any time, either for pottery purposes or as a filler in paper and textile industries. There is always the possibility of finding china-clay in Bihar wherever granitic rocks occur, but no guide to their probable location can be given. White lithomarges which occasionally occur below the widely distributed laterite should also find a market if the colour and quality are good.

Coal.—Although the Jharia and Raniganj coalfields have been carefully surveyed and are well known, the Bokaro and Karanpura fields have not been mapped in equal detail. Certain coal companies have done a considerable amount of work on these fields, and have acquired much information to guide their future mining policies. In these new fields it would have been preferable, perhaps, for Government to have undertaken the preliminary work on this most important mineral asset, and thus have permitted a close control of lease allotment and sequence of working of seams. Even now it is, perhaps, not too late to do this on the western fields.

Copper.—Now that the copper smelter at Maubhandar, Singhbhum, is well established, there is the possibility of other copper deposits, apart from those near Mushabani, being payably mined and the concentrates or ore despatched to Maubhandar for treatment. Ores which years ago could not have been mined payably may now be economic propositions under modern conditions and with a smelting plant already available. The most likely deposits are those along the copper belt, Singhbhum. The possibility of re-opening the Baragunda mine in Hazaribagh district might also be examined.

Glass-sands.—Clean white sands, or pure fine-grained sandstones which can be readily crushed, are likely to be acceptable for the manufacture of glass. River sands are not usually sufficiently clean, but some of the Gondwana sandstones after washing to remove felspathic constituents may prove suitable, and the Vindhyan sandstones should be examined.

Gold.—No hopes are entertained for the development of any valuable gold-mining industry in the province. There is scope for the individual miner, or even for small syndicates, in the south-eastern part of the province. Prospectors are likely to be faced with far more disappointments than successes.

Iron.—Apart from coal, the most important mineral mined in the province is iron-ore. Rich deposits of this ore are mined in places accessible to the railway in Singhbhum. Small deposits do occur elsewhere and it is possible that other small ore-bodies may be found in the future, but they cannot possibly compete with the Singhbhum ores unless they possess some particular property, such as the iron-ore in the Gondwanas which finds an occasional small use as a gas desulphuriser in coke plants, or micaceous hematite which can be used in certain paints. The prospector is not likely to be rewarded for any further search for iron-ore in Bihar.

Kyanite.—Kyanite has found an excellent market in recent years as a refractory, but the deposits of Singhbhum are now almost depleted. The unique deposit of Lapsa Buru is in Kharsawan, outside of the province, but belongs to the same belt as the smaller occurrences in Singhbhum. A continuation of the belt into the Porahat, Singhbhum, is not improbable, but prospects of deposits of kyanite being found there are not bright. Kyanite has been found in other parts of southern Chota Nagpur, but it is the coarse-bladed variety accompanied by quartz or mica. It might be possible to develop a process for separating kyanite from its micaceous or quartz matrix, but such a scheme is unlikely to be utilised in Bihar so long as high grade material is obtainable from Lapsa Buru.

Limestone.—It is unlikely that considerable new occurrences of limestone will be found, except perhaps small deposits in the western part of Chota Nagpur, in Palamau. Good quality limestone always will find a market in Bihar, either for lime-burning, cement manufacture or iron and steel smelting, if accessible.

Dolomite.—The possibility of finding dolomite in the lesser known parts of western Chota Nagpur is by no means slight. Certain deposits are known in the Iron-ore Series of Singhbhum. Although at present there is no considerable demand for dolomite it is not at all improbable that in the near future research will enable the mineral to be used in the place of magnesite as a refractory in steel manufacture.

Magnesite.—Magnesite, if available in Bihar, would find a ready market at the steel works. The mineral does occur 6 miles south of Jamshedpur but is closely associated with talc and it is doubtful whether the pure mineral could be obtained in workable amounts.

Manganese.—Workable manganese-ore deposits are confined to Singhbhum, there appears little likelihood of valuable deposits being found elsewhere in the province. However, the known Singhbhum deposits are being rapidly depleted, the market for the mineral is good, and the possibilities of further deposits being found in western Singhbhum are by no means slight.

Mica.—The mica industry has a long future before it. An increasing proportion of the production is coming from deeper mines. Prospecting for mica pegmatites may be advisably left in the hands of those engaged in the industry, and, apart from possible occasional finds in outcrops of mica-schist outside of the main mica belt, there is no great scope for the casual prospector. It is easy to find pegmatites, the difficulty is to find those which contain payable mica, although at present there is no shortage for fulfilment of normal demands.

Ochres.—Ochres of good quality if found should be acceptable to the paint industry. The quality of most of the ochres in Bihar is suitable only for local colour washing of village huts, but the possibility is always present of good quality ochres being found associated with the less metamorphosed sedimentary and basic igneous Archean rocks.

Silica.—The occurrences of quartz-schist and quartzite are sufficiently widely distributed and known to the users so that no diligent search for these is necessary. If conveniently situated, quartzites can provide a good profit to contractors, who quarry the rock for sale to the railways as ballast or to the refractory users.

Sulphur.—Sulphur is urgently required in India, particularly for the development of chemical industries. The established highly efficient technique of copper smelting in Singhbhum does not permit of an economical extraction of by-product sulphur unless sulphuric acid could be used by a local chemical industry. The mining of these copper deposits for their sulphur content alone is unlikely to be economically feasible, even if use were made also of the resulting copper and iron oxides. Certain pyritic deposits in the Vindhyans of Shahabad deserve to be opened up, and could provide a small but steady supply if a market could be found for pyrites.

Talc.—There is a small market for high-grade fine-grained talc, or soapstone. Deposits are widely scattered in Chota Nagpur, particularly in Singhbhum and Hazaribagh, and these might be carefully examined to determine which of them could be marketed.

Vanadium.—The vanadium-bearing titaniferous magnetites of southern Dhalbhum are unlikely to be of value for some years to come, until the extraction of the vanadium from this type of ore can be made a commercial success. For the present the vanadium output from Peru and Northern Rhodesia leaves no scope for such ores as those in Dhalbhum. It is possible that similar small deposits of vanadium-bearing iron-ores may occur in other parts of southern Chota Nagpur, but there is no point, as yet, in searching for them.

Of the other minerals which have been recorded from time to time in Bihar, aluminium sulphate, antimony, arsenic, bismuth, molybdenite, platinum, tin and zinc, may be regarded now as mineral specimens, having no probable economic value. Corundum occurs with kyanite-rock, raising the latter's alumina content, and blue corundum crystals of no value as gemstones have been found in Manbhum, but no valuable deposits of the mineral alone are likely to be found. Fuller's earth deposits do not appear to be large enough to warrant serious development. The occasional gemstones found are of a semi-precious nature, usually of poor quality and so haphazard in occurrence that no assured industry could be formed. No graphite deposits that could be economically developed have as yet been found, although some of the Archean sedimentary rocks contain quite a high content of amorphous graphite. Much has been written on the lead-silver occurrences of Bihar, some have been worked, but under modern conditions the author sees no possibility of the revival of this industry in the province. Mineral waters may, perhaps, be developed into quite a useful industry, with the opening up of spas at some centres and marketing of the bottled waters. The occasional finds of rare minerals such as triplite, tantalite, etc., have always been disappointing in Bihar but there is still the possibility that during the course of mica-mining useful quantities of such minerals may be found. Saltpetre always will be available in North Bihar.

Summarising the above information the minerals may be divided into four categories. These categories do not, of course, take cognisance of the fact that great changes may be made in the uses to which the minerals are put in any particular industry, and may widen the scope of that industry:

1. Mineral deposits which, if further finds are made, will not now add to the industrial development of the province:

bauxite, clays, coal, iron-ore, limestone, silica. Resources already available in these will permit a considerable expansion of Bihar industry.

2. Minerals of which deposits are already known, but which will depend for their further exploitation on research into their use: apatite, barytes, dolomite, talc, vanadium.
3. Minerals which would always find a market if of the right quality, or large deposits of which would create a market, but are unlikely to be found in large quantity: asbestos, barytes, chromite, gold, kyanite, magnesite, manganese, pyrite.
4. Minerals of which good deposits might still be sought, with likelihood of success: copper, glass materials, mica, ochres. The search for these might be left to the industries concerned, but the advice of Government geologists will be of assistance.

CHAPTER VI.

THE RELATION OF THE STATE TO THE APPLICATION OF GEOLOGICAL KNOWLEDGE

Industrial expansion.

The statements have, at times, been made that knowledge of the minerals of Bihar is scant and that these resources have not been vigorously utilised. It may be said at once that both these statements are untrue: the information summarised in the previous chapter will, it is hoped, dispel the first erroneous belief, whilst the statistics of minerals produced in the province show not only that Bihar leads all other provinces in India, but also that in many cases production has been up to the market's capacity of absorption.

The past vigorous development of the mineral industry does not mean, however, that further expansion is not possible in the future—on the contrary, the province is now and is certain to continue being increasingly industrialised on the basis of its mineral resources. In a few cases this expansion is dependent on exports to overseas countries, but in most it is dependent on the capacity of the province, or of India, to absorb the products. Mineral development in Bihar, therefore, depends mainly upon the extent to which Indian industries can be encouraged to take the mineral products of the province.

The part which the State, as represented by Government, should play in this expansion provides a topic for discussion by many who have deep interest in the mineral industry. The geologist, however, may consider his relation to the mineral industry and to Government from rather a wider viewpoint, and discuss how his acquired knowledge may be used to advantage in several spheres of activity within the State.

Organisation of future prospecting.

In the past, minerals in Bihar have been found in one of three ways: by the Geological Survey of India, by organised prospecting departments of large companies, or by casual finds of villagers brought to the notice of those interested in minerals. All these

factors are still operative, but it has recently been suggested that the provincial Government should itself take a more active and direct interest in prospecting. In which direction is such activity likely to produce useful results?

If the section on future prospecting, in Chapter V, is carefully examined, it will be realised that the scope for the discovery of new minerals is very limited. For the most part the mineral industry is fully able to take care of its own prospecting requirements. Perhaps the only line of useful Government enquiry into new mineral deposits, at present, would be for glass-sands and mineral pigments. Prospecting for other minerals for which there would be a market, such as asbestos, barytes, chromite, copper, gold, graphite, kyanite, lead, manganese and sulphur, is scarcely a task which can be undertaken by a small staff of Government geologists. If the finding of new minerals is to be encouraged, the best results are likely to be obtained by the dissemination of instruction amongst villagers concerning the minerals which could possibly occur in their vicinity, and by the payment of small bonuses for any useful finds.

One of the main functions of the geologist appointed by an industrial concern is the prospecting of mineral leases, which he can examine, foot by foot, in great detail. The function of a Government geologist cannot be that of a prospector, the area which he has to cover is too great for the detailed work necessary in prospecting to be possible normally. During the course of his mapping, however, mineral deposits may be found, or local villagers may draw his attention to them. The primary function of the Government geologist, mapping, apart from the accompanying fortuitous finding of minerals, enables him to advise on and guide to limited areas the prospecting efforts of others. Once an industry has been established it also becomes one of his functions to assist that industry in the conservation of its resources and guide it in its mining. In addition, his advice may be sought on many other lines of enquiry some of them not related to mineral deposits, such as have been enumerated in Chapter IV.

Vesting of mineral rights : State and Zamindar.

A very large proportion of the mineral resources of Bihar is in zamindari land. In such cases Government obtains neither rents nor royalties from the minerals. But it does not necessarily follow that the province obtains no benefit from the development of such

deposits, for they add to the employment of labour and general increasing industrialisation of Bihar.

Frequently the mineral rights of zamindari land are split into innumerable shares, and litigation only too often hinders the successful development of mineral deposits. There have also been cases in which the desire to mine privately-owned minerals as cheaply as possible have resulted in a brief life for the deposits and loss of considerable reserves. In addition there is the danger that the terms demanded by zamindars before leasing their mineral rights may be so excessive that they may either make prohibitive the development of the deposits or soon force the miners into liquidation. It would be advisable to standardise lease terms for zamindari land on lines similar to those issued by Government for *khas mahal* mineral areas. In addition, to protect the zamindar, examination of the technical credentials of those who desire mineral leases in zamindari land may be beneficial.

On the coalfields, the positions of lease boundaries, governed by the limits of zamindari property, may not be the most suitable for the maximum efficiency in mining technique, or for conserving the reserves of the seams.

There is little doubt that, from the point of view of the State, the continuation of the mineral rights vested in zamindars is not to the ultimate advantage of future industrial development and does not lead to the conservation of mineral resources within the State. It must be emphasised that mineral deposits are a wasting asset, resources lost through inefficient mining or treatment can never be recovered and ultimately the State is the loser.

Rents and royalties.

In *khas mahal* land the determination of the amounts of rents and royalties which Government should impose, should be founded on a knowledge of the various factors which may affect the particular industry. The object, in principle, is to obtain the maximum revenue for Government, which will not, however, bear unduly heavily on the miner and prevent his efficient working of a mineral deposit.

In most cases rents are payable in two parts:—(*a*) dead rent payable for the area of the mining lease itself, and (*b*) surface rent payable on land occupied by works, offices, and quarters. Usually dead rent may be regarded as a minimum royalty, as only that

which is the greater, dead rent or royalty, is payable in any one year. For iron-ore the minimum dead rent in the past was one anna per acre, for coal, bauxite, pyrites and alkali salts 4 annas per acre, and for all other minerals a minimum of one rupee per acre. Recently dead rents have been levied at values which vary for individual cases. Surface rent is a fixed amount dependent on the actual local value of the land occupied, and assessable under the revenue and rent law.

As a general rule it may be said that in the first year or so of opening up a new deposit the dead rent will be paid, whereas later, when the deposit is worked vigorously, royalty will provide the main form of revenue to Government for the deposit. The amount of dead rent payable should not be so excessive as to hinder working, and it should vary according to the type and size of the individual deposit. Some minerals may have a low market value and may be in small pockets scattered over a wide area—obviously, in such a case, the dead rent should be very low. In another case deposits of a more valuable mineral may be scattered over an equally wide area, and here a somewhat higher dead rent is advisable. Yet again, a mineral of low value may be concentrated in a small area, so that a dead rent higher than in the first case is permissible, whilst if large reserves of a mineral of high value are concentrated in a small area a commensurately high dead rent is legitimate.

Although it is advisable to keep dead rents at rates which will not hinder development, there may be the danger, if the rates are very low, of the deposits being taken on lease by inefficient concerns which have not the requisite capital to work the minerals vigorously. An inefficient and under-capitalised concern often means that Government is losing revenue on royalties which a more efficient company would have paid, and that ultimately large assets may be lost to Government because of wasteful working. Also, if the dead rent is too low, the tendency will be for the lessee to obtain a larger area than is really necessary.

The area covered by a mining lease will, of course, vary with the particular type of mineral deposit. In general, deposits like coal, iron-ore, limestone and copper require a considerably larger lease area than say china-clay, ochres and gold. The areas of iron-ore leases in Singhbhum, for the larger companies, have usally been based on 100 years supply of ore, according to the estimated annual requirements of each company. Where several deposits of a mineral

are scattered over a fairly limited area, the lessee should not be permitted to take up a number of separate l leases leaving small unleased areas between, but should be compelled to take the whole within reasonable limits.

A most excellent method of lease allotment has been adopted for the mica pegmatites of the Kodarma Reserved Forest. Here a great number of pegmatites are scattered over a large part of the forest area. The forest has been divided into 900 squares of 40 acre each and these are leased out at a fixed rent for each square (now Rs. 12 per acre), no royalty being now charged on the mica produced. However, many of these squares are geologically incapable of yielding mica pegmatites, and are not advisedly taken up on lease, in others the geology is such that only a portion of a square can possibly carry mica pegmatites. It is only equitable that the rent on the latter should be lower than on those squares which may carry mica pegmatites throughout. It would be quite a simple matter to base the rent to be charged on the evidence provided by the geological map. The method of lease allotment which has proved so suitable to the mica deposits of the Kodarma Reserved Forest, is not necessarily applicable to other types of deposits, and should not be normally applied elsewhere. It is applicable in the Kodarma Reserved Forest only because the deposits are numerous and closely spaced. Outside of the Reserved Forest in zamindari land, the mica deposits are more widely spaced and the method of division into 40 acres squares is not feasible.

Minerals in the ground are amongst the State's important assets, but they are wasting assets, for once removed they can never be replaced. It is, therefore, the State's right to obtain a fair return for the sale of these assets and the normal means of securing this return is by charging royalties on the mineral removed.

The value of a mineral varies according to different stages of its production; it has one value to the miner as it lies in the ground, another value on being brought to the surface (known as the pit's mouth value) and other values as it reaches various points of transport and ultimately the place of manufacture where it is to be converted into finished articles. The increase in value depends on labour costs, transport charges, etc., through the various stages. Theoretically then, the value of the mineral *in the ground* is the difference between the sale price of the raw material and all labour and other charges from the moment of commencement of mining it.

This value may be regarded as divisible into two parts: the value to the State, which is in other words the royalty, and the additional value to the miner, representing the latter's profit. That is, royalty represents the State's selling price of a mineral in the ground.

The difficulties of calculation of this theoretical value have led to simpler methods of assessment, but the methods to be adopted in charging royalties, and the amounts, give rise to difficult problems, for there is no consistent basis of determination which may be regarded as equitable for all deposits. Under the Mining Rules in the past, apart from special rates of 5 percent for coal, $7\frac{1}{2}$ percent on the annual profits or $2\frac{1}{2}$ percent on the gross value for gold and silver, 1 anna per ton for iron, and 30 percent of the annual net profits for precious stones, the general basis of assessment of royalty for most minerals has been $2\frac{1}{2}$ percent of the 'pit's mouth' value of the mineral, but a flat rate has been commonly substituted for some minerals. The amount, $2\frac{1}{2}$ percent, was presumably based on past experience of what industry can afford to pay compatible with Government's revenue requirements, but this cannot always be accepted as an *a priori* reason for future levies at the same rate, and, in fact, the Bihar Government has recently raised the rate to 5 percent.

Before proceeding with this discussion it is advisable to define some of the terms used.

By 'pit's mouth' value of a mineral is meant the market value of the mineral, less transport and other charges incurred subsequent to despatch of the mineral from the mine.

The geologist imposes a definite restriction on the use of the term 'ore', which is not always appreciated. An ore is a mineral aggregate containing a sufficient percentage of *metallic* constituents permitting it to be economically mined, treated, and marketed. The term is not applied to non-metallic mineral aggregates like sand, clay, talc, mica pegmatite, which are not mined for any metallic content. It will be noted that the use of the term 'ore' implies 'grade'—if the grade is lower than that at which a profit can be made then the mineral is not, strictly, ore. Sometimes an ore is divided into several grades called for example first, second, and third grade ore, according to whether the quality is high or lower.

Obviously, then, royalty should be charged only on ore in the case of metallic minerals, and, in the case of others, on that material

which it is payable to work. In general terms, royalty should be charged only on the product which is actually despatched from the mine for marketing.

Iron-ore may be quoted as an example of the points which must be taken into consideration in determining royalty:

In Bihar the percentage limit for iron-ore is about 60 percent iron—below that grade this type of ore cannot usually, in this country, be economically smelted. Included in these deposits there are large amounts of loose fine material which cannot as yet be economically treated in this country, although it can be used in other countries. Such fines are, however, piled at the mines for use in the future, and are not therefore wasted. Although these fines must be mined, along with the solid ore, they are not despatched from the mines and are correctly not subject to royalty. In the early days of iron mining in Bihar a low rate of royalty, one anna per ton, was fixed in order to encourage the industry. Now that this industry is well established a higher royalty may be charged. However, in view of the fact that equally high grade ore is available in the adjacent Orissa States, some of which may be better suited to certain purposes, an excessive raising of the royalty rate might lead to an extensive transference of mining from Bihar to the States. Although the more equitable basis of levying royalty would be on the average iron-content of the tonnage despatched for treatment, the grade of iron-ore despatched to the smelters varies so little that the simplest method is to levy at so much per ton of ore.

Certain forms of soft or powdered iron-ore may be used for other purposes, such as for desulphurising coke-oven gases, or in the manufacture of special paints. Such materials should not be treated on the same basis as iron-ore smelted for iron, as they may be sold for a higher price and should, therefore, be subject to a higher royalty.

In the case of other ores, such as manganese, chromite or copper, there may be a wide variation in composition or grade of the ores mined, and it would not be equitable to charge a flat rate of royalty for all grades of each mineral. The alternative then is to charge a separate rate of royalty for each grade of ore, first, second or third grade as the case may be, or charge royalty at so much per unit of metal in the ore. The latter is certainly the most equitable basis of calculating royalty, but it occasions a considerable amount of trouble in checking mining returns and analyses.

The market price of minerals varies from time to time. If the royalty is charged at a flat rate Government is not receiving an equitable return when the price is high, and the miner may be subjected to a heavy burden when the market price is low. In the case of minerals in which the royalty is 5 percent of the pit's mouth value, the royalty will vary according to the market price, but on account of the inconvenience and labour involved in assessing these rates of royalty, a sliding scale is often adopted in which the royalty varies periodically with the market price.

It will be seen, therefore, that the method by which royalty is to be charged should be considered separately for each type of deposit. Certain minerals such as iron-ore do not vary widely in value and for them a flat rate is a simple and reasonably equitable method of assessment. For those in which the valuable constituent is subject to wide fluctuations in price some form of sliding scale is equitable.

Some provision should be made in the terms of each lease for a revision of the royalty rate periodically, as the status of an industry may alter. When an industry is in its infancy low royalties form a desirable encouragement, but once the industry is well-established and as its ramifications extend Government is entitled to an increased share in that industry's prosperity. Or, again, a local mining industry may suffer adverse changes in consequence of competition by overseas mines. At the same time, the basis of royalty charges should be as uniform as possible throughout India, otherwise an undesirable competition between provinces may result.

Some actual royalty rates may be quoted in order to illustrate how these vary from place to place:

Iron-ore.—Bihar (up to 1938), one anna per ton if the tariff value of imported pig iron is not greater than Rs. 65 per ton, and one anna per ton more for every Rs. 15 or part thereof by which the tariff value of the iron exceeds Rs. 65 per ton. Since 1938, 4 annas per ton is being charged pending final decision of Government.

Coal.—Bihar, 5 percent on the sale value at the pit's mouth with a minimum of 2 annas per ton. For coal dust, half the rate fixed for coal.

Manganese.—Bihar, 12 annas per ton for high-grade ore (47 percent Mn and over) or 10 percent of the pit's mouth value when the price is Rs. 10 or under, subject to a minimum of 9 annas *plus*

an additional royalty of 20 percent of the sum by which the pit's mouth price exceeds Rs. 10 per ton and an additional royalty of 10 percent of the amount by which the pit's mouth value exceeds Rs. 20; 6 annas per ton for low-grade ore. Keonjhar, 6 annas per ton for manganese-ore and 4 annas per ton for manganiferous iron-ore. Central Provinces, 5 percent. Mysore, 10 annas per ton.

Chromite.—Bihar, Rs. 1-8 per ton for concentrates when the pit's mouth value is Rs. 10; Re. 1 or less per ton for lump ore *plus* an additional royalty of 20 percent of the amount by which the pit's mouth value exceeds Rs. 10, *plus* an additional royalty of 10 percent of the amount by which the pit's mouth value exceeds Rs. 20; 7 annas per ton for low-grade ores (usually less than 47 percent Cr_2O_3). Baluchistan, 12 annas per ton. Mysore, Rs. 1-8 per ton. Bombay, 6 annas per ton. Southern Rhodesia, 5 pence per ton. Sierra Leone, 1/3*d.* per ton. Cyprus, 1/6*d.* per ton.

Kyanite.—Bihar, Rs. 1-8 per ton.

Limestone.—Bihar, 9¾ annas per ton for a quarry within 5 miles of a public railway station, 6 annas per ton if within 5—15 miles of a railway station, 4 annas 10 pies if more than 15 miles from a public railway station. Central Provinces, 4—5 annas per 100 mds. according to locality. Gangpur, 6 annas per 100 cu. ft.

White clay.—Bihar, Re. 1 per ton of refined clay when the pit's mouth price is Rs. 20 or under, *plus* an additional royalty of 20 percent of the amount by which the pit's mouth value exceeds Rs. 20 per ton; annas twelve per ton for crude clay.

Gold and silver.—Bihar, 7½ percent on the profits of each year taken separately, or 2½ percent of the gross value, at the option of Government.

Precious stones.—Bihar, 30 percent of the net profits of each year taken separately.

Minerals for which no special rates have been provided: Bihar, 5 percent on the sale value at the pit's mouth.

From time to time it may be advisable for Government to consider levying other taxes on the mineral industry, such as on the finished product. For example, in coal mining, it has been estimated that the additional cess and taxes in various forms totals about 7 annas per ton of coal. In some cases the industry may be well able to afford such additional taxation, but in others such taxes may even go so far as to destroy the industry. The trade in

some minerals has remarkably wide ramifications and may be affected by conditions in widely distant parts of the world; these must all be appreciated whenever taxation in any form is to be considered.

An important aspect of lease allotment is the period for which leases should be granted. Some deposits are small and a long lease is unnecessary. Others, such as for iron-ore, are large and take an extended period to deplete. Most deposits require machinery to work them and the period of depreciation on such capital expenditure permitted for income tax purposes is 20 years. Hence, a minimum of 20 years is generally advisable for mineral leases, 30 years being preferable.

The above points have been considered in very general terms, as the object has been not to lay down rules but merely to outline the factors to be considered in determining rents and royalties. Every mineral deposit deserves separate consideration to obtain as balanced an assessment as possible both on behalf of Government's revenues and for the benefit of the industry's development. These questions require the technical advice of geologists, which is always available in the Geological Survey of India.

In concluding this section, recent litigation suggests that a brief item of advice may here prove apposite for prospective lessees and lessors. Any lease agreement which permits the removal, from the surface or from under the surface, of any mineral material, whether it be soil, gravel, rock, ore, or any other form of mineral aggregate, and which is to be used for any purpose whatever elsewhere, should state explicitly whether royalty is or is not to be paid on this material, or state that rent is to be regarded as payment in lieu of royalty. This will avoid all possibility of litigation, as there have been cases in which the presumed legal as against the true definition of the term "mineral" has been used as a basis for claiming or refusing to pay royalty on mineral substances removed from a lease area.

Some aspects of mineral development.

It is, of course, obvious that the greatest benefit will accrue to the country by making the maximum use of local mineral raw materials in domestic industries. To encourage those who will utilise the minerals in the country they should be given favoured treatment in lease assignment.

The value of certain mineral deposits is so great to domestic industries that they should be reserved entirely for those industries and export prohibited. For example, the manganese deposits of Singhbhum and the Orissa States are of inestimable value to the Indian iron and steel trade as they are much more accessible to the steel works than are the ores of the Central Provinces. Continuation of export of the latter is advisable, but export overseas of manganese-ores from Singhbhum and the Orissa States should not only be prohibited but the deposits should be leased preferably only to those who will utilise the ores in Indian industries.

There are vast resources of iron-ore in India, and there is no reason why, under normal trading conditions, any restriction should be placed on exports. In Singhbhum, there are two types of iron-ore deposits: (*a*) deposits of "solid" or bedded iron-ores and (*b*) surface debris, called "float" ore or "cemented float". The former deposits contain the vast reserves and they will be the sites of iron-ore mines probably for centuries to come. The float deposits consist usually of surface debris scattered over a wide area of country; they are of only temporary significance. As it happens, most of the iron-ore mined in Singhbhum for export from India to date has been from float deposits.

It is apparent that the mining of solid iron-ore will destroy the forest in the immediate vicinity of the ore-bodies, but such sites will remain practically permanent mines, individually at least for scores of years. The value of the ore obtained, particularly if smelted in the country, will be many times greater than that of the forest destroyed.

In the case of float ore, so long as loose fragments are merely collected from the surface no damage is done, in fact possibly the surface soil may be improved. But wherever the soil is excavated to extract the ore debris, there a considerable amount of damage is done to the surface, and regeneration of forests may be retarded for many years. This damage may exceed the value to the country of the ore obtained.

There is plenty of solid ore available in this region, and there seems no sound reason why tracts of country should be damaged merely to obtain cheaply mined debris or float ore. It would be preferable to refuse to grant leases over areas in which there is only float ore, but in leases which contain solid ore the accompanying float should be permissibly extracted.

The coal industry has many problems which require urgent settlement. Perhaps more than for any other mineral a rational use of coal is necessary, not only in order to obtain the maximum value from production, but also to conserve the country's restricted resources. Reserves of coking coals are limited, but valuable coking coals are being used as steam coals. The extra railway freight on Jharia coals as compared with Raniganj coals for the Calcutta market has in some cases led to such a reduction of mining costs in the Jharia field that wasteful methods have been adopted in the past. Intense competition, particularly amongst many of the smaller companies, with over-production, has also had the same result. The better quality coals have been rapidly extracted and, as a consequence, overlying seams of inferior coal have been destroyed in many places, and vast reserves lost. In some cases large reserves of even the best grades of coking coals have been lost through various causes. Sand-stowing may help in supplying support for the overlying seams in many places, but most of the past losses are now irrecoverable.

A desideratum, towards which some endeavour should be made, is the working of all seams, from top to bottom, of inferior and better grades, coking and non-coking coals, according to a definite coordinated sequence, so that the full resources will be extracted and, in any section of the coalfields, all the seams will be exhausted together. This will necessitate a more rational scheme also of marketing and using the coal, possibly of compulsion in the use of inferior grades for certain purposes—research on blending and the improvement of grade by cleaning may be helpful here. It is apparent that all this would require widespread reorganisation of the whole industry, with compulsory cooperation which is unlikely to be obtained without some form of Government control.

Ultimately, from the points of view of both mineral conservation and the most thorough use of the country's resources, it is preferable to encourage those with plenty of capital to develop mineral deposits rather than those who have very little capital. Coal, iron-ore, copper-ore, bauxite, clays, chromite, manganese, limestone, and mica, all require considerable investments to mine them efficiently, and to ensure that the minimum of reserves are lost. There is still scope for the small miner in minerals like sands, ochres, soapstone, road metal, railway ballast, and small gold veins.

It is not always advisable to hasten the mining of certain minerals. By delaying their development until related industries are established such minerals may find a more valuable use within the country.

An important aspect of mineral utilisation is a knowledge of the actual quantities of various raw materials produced within the country. Statistics of mineral production in Bihar, as in other parts of India, are incomplete. Only mine owners who are within the scope of the Mines Act submit returns of production, others, especially in zamindari land, submit no returns. It is important that returns of production from all mines, however small, be compulsorily submitted through the district officers to some central department such as the Geological Survey.

From time to time mine owners have been forced to object to rulings by Income Tax Commissioners on the distinction between revenue and capital expenditure in mining. These objections have frequently been legitimate and have been made necessary in consequence of the fact that Income Tax officers are not familiar with the technique of mining, but at times regard certain items of expenditure from the point of view of other forms of business. Unlike all other industries, mining is based on the extraction of a wasting asset, an asset which, once taken from the ground, is never renewed. It would be of advantage to the mining industry if the Income Tax authorities would make use of some form of permanent technical arbitration committee for advice on such matters.

Industries to develop.

The steps to be taken in the development of industry are outside of the sphere of the geologist's activities, but, in view of his acquaintance with the resources of raw materials available, his advice on the direction which development should take may be pertinent.

Amongst approximately forty varieties of mineral deposits which occur in Bihar quite a number are the basis of firmly-established industries, such as the clay, coal, copper, iron-ore, limestone, and mica industries, and almost all of which have a considerable and healthy future before them.

Of quite a number of the recorded minerals, such as antimony, arsenic, molybdenite, platinum, tin, tungsten, and zinc, no deposits of a workable nature occur, and it would be futile to hope for any industry in them.

It should be possible, in the case of several of the remaining minerals, to establish a market for them, or to manufacture the raw materials into marketable goods within the province, or, in some cases, to create subsidiary branches in already established industries. Such development will depend mainly upon research which may be undertaken either by the industries themselves, by universities and colleges, or by Government.

The possibility of establishing an abrasive industry in the province might be investigated. Several of the natural abrasives occur, such as quartz, garnet, lime, talc, and the raw materials for the manufacture of artificial abrasives, silica and alumina, also are available. The problem is twofold: costs and market demand. and of the two the latter would appear to be the main. The Indian market for artificial abrasives is unlikely to be sufficient until other industries develop further, and exports would have to face the strong competition of an established American and continental industry.

Excellent phosphate deposits, apatite, are lying practically idle in Singhbhum for want of a local market. There is scope here for research, two lines of which are at once apparent: research by the iron and steel industries into the use of phosphate for the manufacture of special metal, and research by Government into the use of apatite in agriculture or for other purposes.

Barytes deposits occur, but research might be undertaken by a university to determine the possibility of creating a small industry for the extraction of barium salts.

The use of bauxite for the extraction of aluminium has been long delayed in India, but the establishment of works to treat the Bihar ore has at last been mooted. From the point of view of research the aluminium industry should be capable of taking care of its own requirements. The use of bauxite in other industries is also now sufficiently well known to require no research assistance, but there may be scope for the establishment of such industries as the manufacture of abrasives and aluminum salts. Its use in the manufacture of alumina cements has already been investigated and the erection of a plant for the manufacture of this material is likely in the near future.

Although building and ornamental stones are available in the province there seems little likelihood that their use will expand. Some attempt may be made, perhaps, to develop amongst Biharis an appreciation of the fine appearance of these stones.

The chromite of Singhbhum has been used to some extent as a refractory in the manufacture of chrome-brick, but its use in this direction appears to be limited and it is not so suitable as Baluchistan chromite. Deposits are not large and the maximum value would be obtained from the ore either by converting it into ferrochrome or into alkali bichromate. In the former case the steel companies could presumably carry out the necessary research, and in the latter a university might be of assistance in working out a process.

The ceramic and refractory industries may be safely left to develop up to the market's capacity. The obtaining of supplies of the highest grade of china-clays will always be a difficulty, restricting this side of the ceramic industry.

The coal industry is thoroughly well established, but there is undoubtedly vast scope for research into the better and wider uses to which this fuel and its by-products could be placed. Although the coking plants within the province are actively and efficiently playing their part in such research, from the point of view of their own and related requirements, there are many other lines of investigation awaiting the fuel researcher. It may be advisable, in the near future, to establish a fuel research institute. Amongst important lines of investigation are the following: the cleaning of many of the high ash coking coals; the more efficient use of pulverised coal; improvements in the domestic fuel industry and the recovery of by-products; tests on ash fusibility; the blending of coals for coking; the possibilities of briquetting. A comprehensive chemical and physical survey of the coalfields might be invaluable. All of these investigations would eventually lead to the expanded use of coal and also perhaps to an increase in the resources available. In view of the limited resources of metallurgical coking coals in India, it has become almost imperative that this class of coal should not avoidably be used for railway and other purposes, but should be reserved wherever possible for the purpose to which it is so essential.

Research on glass-sands is, apparently, being undertaken by university workers, and if successful may lead to the establishment of a considerable glass industry within the province. The possible utilisation of soda felspars from the pegmatites of the mica belt might be investigated.

The kyanite deposits of Lapsa Buru, Kharsawan State, are unrivalled anywhere in the world. Most of this material, both from

Kharsawan and Singhbhum, has been shipped abroad for manufacture into refractory bricks or special porcelains. So far it has been possible to utilise only a small amount in India. As in most raw materials, the value lies not in the price of the raw material itself, but in the industry created by manufacturing it into marketable goods. It should be possible to manufacture in Bihar not only increased amounts of refractory brick, but also special porcelains. Research on these lines by the ceramic industry may require the cooperation of Government.

The manganese deposits of Singhbhum are small, but some of them have been proved to be high-grade, and even chemical ore has been mined. The possibilities of increasing the amount of ferromanganese manufactured in the country may be safely left to the steel companies. All new occurrences of manganese-ore should be carefully examined for their possible use in the glass industry or for the manufacture of dry batteries.

The mica industry is well established, and its trade channels and processes form a most intricate study. The pre-eminence of Bihar's mica trade in the world depends not only on the large size and quality of the mica, but also on the cheapness and expertness with which splittings can be manufactured by local labour. Indeed, mica is now imported into India in quite considerable quantities, for conversion into splittings which are re-exported. Apart from splittings, practically the whole of the block mica produced is exported as such, only a very small amount is manufactured into condenser films, washers, etc. However, the industry in manufactured mica is slowly but surely increasing and, with firmness in marketing abroad, there is little doubt that it could become one of the most important branches of the mica trade in Bihar. The manufacture of micanite on a large scale in India will undoubtedly be undertaken in the future. A spirit of cooperation with elimination of, at times, almost crippling competition, are perhaps the most important requirements in the industry, if the province, as well as the companies, is to obtain all the benefit that it should from this industry. Looked at from the point of view of Government, the workers engaged in the industry, and conservation of the mica reserves, eventual compulsory enforcement of cooperation may become desirable.

The utilisation of the mineral waters in Bihar has been almost completely neglected. Research into the quality of these

waters has been commenced by the Geological Survey of India. It should not be difficult for the provincial Government to open up health spas, and undertake the bottling and sale of certain of the waters.

Research into the wider utilisation of the steatite deposits which are found in several parts of Bihar, would appear likely to provide interesting and perhaps valuable results. Such research may be undertaken by university workers.

Geological research in Bihar.

The lines upon which future prospecting may be undertaken in Bihar and the allocation of such work and of research on the utilisation of minerals have been outlined in the previous pages. But mineral investigations form only a part of the work of geologists, and, in Bihar, there is scope for a wide field of practical geological research which will be of benefit to the province.

Geologists working in Bihar are attached to various institutions, and include officers of the Geological Survey of India, geologists of industrial concerns, and university and college teachers and research workers. To obtain the maximum result from the services of these workers the lines of investigation to which they are best suited should be clearly recognised.

The work of officers of the Geological Survey must be extremely broad. It is a long-established and all-time service, and must necessarily take an interest in all phases of geology. Its basis is the detailed geological mapping of the country, and from this springs its ability to give expert advice on such matters as prospecting, development of mineral industries, problems affecting the relations between Government and the mineral industries, water supply, and geology as related to such engineering problems as structural foundations and building materials, and soil surveys.

The industrial geologist is concerned more particularly with mineral deposits in which his firm is interested, and occasionally also with engineering problems. He frequently contributes information which is of invaluable assistance to other geologists, and recognition of the value of such interchange of ideas is of immense use to himself and his firm.

The university and college teacher has a twofold function. Primarily he is a teacher, and geological research can be undertaken only in his spare time. For the best use to be made of his

services, lines of investigation must be chosen which are suited to the time and means at his disposal.

There is a great need for a detailed study of the development of the physiographical structure of Bihar. This could best be undertaken by university workers during their vacation periods. It would help to provide invaluable information on river movements and flooding, and on soil erosion. The geological aspect of soil surveys and soil erosion could be also investigated by university workers, but these problems must necessarily be studied in great detail.

The general study of underground water throughout the province, but particularly in North Bihar, is desirable. This would include the compilation of an immense amount of detail concerning all tube-wells put down in North Bihar so that eventually the water-horizons will be fully understood and the best use made of them. Such work could be readily carried out by university workers who are on the permanent staff, as continuity of study is imperative. Alternatively, such a detailed and continuous study as this could be carried out by a geologist working under the Geological Survey but permanently attached to Bihar.

The need has now arisen for the determination of a plan of water storage in Bihar for the future. Sites should be allotted which may ultimately be taken up by the Bengal and Bihar authorities respectively. Sites should also be allotted separately for irrigation, hydro-electric and town supply schemes. Unless such allocation of sites is made now, difficult problems will arise in the near future. In preparing such a plan the services of the Geological Survey should be called in consultation with the engineer preparing the scheme.

In most engineering problems where geological advice is necessary the services of the Geological Survey provides the widest experience. In North Bihar, the relation of building sites to earthquake effects should always be considered in cooperation with experienced geological advice.

PART II.—THE MINERAL INDUSTRY OF BIHAR

CHAPTER VII.

ABRASIVES AND GRINDING MATERIALS.

Introduction.

An important requirement of almost all phases of industry is the use of materials for cutting, abrading, polishing, crushing, and grinding. These may be used as powders of all degrees of fineness, as cutting or grinding wheels, or as pebbles in grinding mills for paint, clays, etc.

The natural or mineral abrasives have been considerably replaced by artificial products in recent years, particularly for metal work. The manufacture of artificial abrasives has become an industry of great importance, but one which has scarcely found a footing as yet in India, notwithstanding the availability of the mineral raw materials for its establishment.

The most essential property of an abrasive is hardness, as it is on this that the cutting or abrading power of the material depends. With this, however, must be combined toughness, for the effect of hardness will be annulled if the material breaks up readily under the shattering action of the process of abrading. At one time, the classification of hardness of abrasives was based on Moh's scale, in which minerals were graded from 1 (talc) to 10 (diamond), the harder minerals of this classification being felspar (6) quartz (7), topaz (8), corundum (9), diamond (10). The intervals between each number on this scale did not by any means represent equal differences in degree of hardness. With the widespread use in recent years of artificial abrasives, this scale has been extended to: quartz (8), topaz and garnet (10), corundum and tungsten carbide (12), silicon carbide (13), boron carbide (14), diamond (15). There is still no artificial compound harder than diamond, but the latter's rarity restricts its use.

Natural abrasives.

The natural abrasives are classed into "high-grade natural abrasives" and "siliceous abrasives".

The high-grade natural abrasives include diamond, corundum, emery and garnet as the principal minerals. Of these, diamonds are not found in Bihar, corundum is found associated with kyanite in Manbhum and Singhbhum (see Chapter XXI), and only garnet is known to occur in quantities sufficient to be used as an abrasive. Garnet sands occur along the streams which traverse the mica-schists in northeastern Dhalbhum, and, until recently, they were collected by the villagers near Malibani (22° 23′ : 86° 42′). Similar garnet-bearing stream sands may be found occasionally in Hazaribagh district. On the southwest side of Shirbai *dungri* (22° 20′ : 86° 39′), in Singhbhum, a segregation of garnet-rock is known to occur. However, although the garnet sands in Dhalbhum, in particular, may be useful as an abrasive there appears to be no market for them nowadays.

The "siliceous abrasives" comprise the various forms of free silica: quartz, sand, sandstone, quartzite, flint, chert, tripoli, diatomite, with also various materials which depend on their quartz or silicate content for their abrading properties, such as silt, siliceous shales and clays, siliceous limestone, pumice, volcanic dust, rottenstone, felspar and granite.

Sands are used for cutting, polishing and burnishing. For this purpose either river sands may be used or friable sandstones which may be readily crushed. In Bihar, most of the river sands are rather too coarse for this purpose and would need to be further ground. There are certain friable sandstones of Vindhyan age along the Son Valley, west of Dehri-on-Son, and south of latitude 24° 50′ (see also "sands" in Chapter XVIII) which could be easily crushed and used for this purpose. Sands are also used for the manufacture of sandpapers, and for this purpose crushed and graded quartz, either from river sands or quartz veins, is suitable.

The milder abrasives such as pumice, volcanic dust, tripoli, diatomite, china-clay, chalk, lime, talc and ground felspars, are used generally in the powdered form for putting a finishing surface on wood and fine metallic instruments, or for such domestic purposes as scouring and cleaning. Of these materials, pumice, volcanic dust, tripoli, diatomite and chalk are not available in Bihar. The province's resources of china-clay are described in Chapter XV, lime in Chapter XXIII, talc in Chapter XXX and felspar in Chapter XXVI, and for abrasives of this nature the province is well-provided

should an industry for the marketing of these powders be established at any time.

Sandstones of a fine-grained even texture are used as grindstones, sharpening hones, and as millstones. These may be obtained more particularly from amongst the Vindhyan sandstones of Shahabad district.

Quartzites may be used as millstones, and sharpening hones, provided they are fine-grained. Quartzites of this quality are found amongst the Archean rocks of almost every district in Chota Nagpur, and also amongst the Vindhyans of Shahabad district.

Granite and trap are sometimes used for millstones; the fine-grained granites of Chota Nagpur, the traps of the Rajmahal hills, the Archean lavas, and dolerite dykes, are all suitable and readily available.

Amongst the Vindhyan rocks of United Provinces there is a peculiar extremely fine-grained siliceous rock known as *porcellanite* which would be ideal for use as hones or sharpening stones. It is possible that this rock may also occur in the Vindhyans of Shahabad district.

Pebbles of flint, chert, or fine dense quartzite find a use in mills for grinding limestone, cement, ore, paint, clays, etc., although nowadays they have been largely replaced by steel balls. However, particularly in pottery work where contamination with iron must be avoided, such pebbles are still used. Flints and cherts may be found amongst the Rajmahal traps, but are not abundant. In southern Singhbhum there are beds of pure white chert in the Iron-ore Series, particularly to the northeast of Jamda (22° 10′ : 85° 26′), and pebbles shed from these and strewn along the stream-courses would be suitable for use in grinding mills. In southern Dhalbhum other beds of chert have also supplied adjacent streams with chert pebbles. Beds of impure chert are abundant north of chandil (22° 57′ : 86° 04′), Manbhum.

Artificial abrasives.

The manufactured non-metallic abrasives which are now on the market and imported into India are: (1) Silicon carbide (*e.g.*, carborundum), (2) fused alumina (*e.g.*, alundum), and (3) boron carbide (norbide). Their manufacture depends on the availability of cheap sources of power, and this is usually associated with hydro-electric schemes. However, should the generation of power be

taken up on a large scale in Bihar, with consequent reduction in costs per unit in view of the cheapness of coal supplies on the coal fields, it should not be difficult for either silicon carbide or fused alumina to be made in the province. Silica, in the form of quartz sands, and alumina, as bauxite, are readily available. There seems no reason why such an industry should not be able to market its production even overseas, in competition, say, with American products.

Future trend.

There is scope in Bihar for the utilisation of such materials as sand, clays, lime, talc, felspar, in the powdered form as abrasives. In addition, the utilisation of special stones, such as porcellanite, as hones, might be investigated. With the introduction of artificial grinding wheels, the use of sandstones, quartzites, etc., as grindstones is likely to diminish, although their use as millstones may continue. In view of the rapid growth of industry in India the possibilities of the establishment of an artificial abrasive industry may well repay investigation.

CHAPTER VIII.

ALKALI SALTS.

General.

The alkali salts produced in Bihar include potassium nitrate (saltpetre), sodium carbonate, and sodium sulphate. The industry dates back many centuries and is still of importance in many parts of North Bihar. Indeed, at one time, this part of India possessed almost a monopoly of the world's supply of nitrates.

The alkali salts are found as an efflorescence on the surface of the soil, which, where sodium salts predominate, is rendered largely sterile. These salts accumulate in the sub-soil water, due to the breakdown of alkaline constituents in the soil, and, during the hot months, the solutions ascend and evaporate at the surface leaving an accumulation of salt as an efflorescence. Common salt and sodium sulphate are the most abundant constituents of these mixed salts, but in some places sodium carbonate predominates and potassium nitrate is found where the soil is charged with organic nitrogeneous matter.

Uses.

Saltpetre produced in Bihar is used mainly as a fertiliser, providing both nitrogen and potassium to the soil. In addition it is used in the manufacture of explosives and in the chemical industry.

In Bihar, sodium carbonate is used in the glass and soap industries, and sodium sulphate finds a use in curing hides and skins, tanning leather, and as a veterinary medicine.

Saltpetre.

The nitrates necessary for the formation of saltpetre have accumulated in the course of centuries in the soil of this highly populated area. The North Bihar villages, built on the sites of previous tumbled villages of mud huts, become raised above the level of the surrounding country. The floors of these huts are invariably made of mud and cow-dung, forming a nitrogeneous deposit to which is added other animal refuse and the ashes of innumerable fires, which contain potash. The decaying refuse undergoes nitrification, and

the product drains from the raised village sites into the surrounding fields at a lower level. In the dry season the salts are brought to the surface as a mixed efflorescence of sodium chloride, sodium sulphate, sodium carbonate and nitrates of potash and magnesia.

TABLE 2.—*Production of saltpetre.*

Year.	Bihar.	India.
	Tons.	Tons.
1929-30	572	5,488
1930 31	853	7,309
1931-32	1,091	7,652
1932-33	1,477	8,541
1933-34	2,311	11,263
1934-35	2,327	10,802
1935-36	2,953	12,623
1936-37	1,004	11,218
1937-38	963	8,632
1938-39	1,324	8,708

The amount of saltpetre in the soil collected varies between 1 and 29 percent, but is normally less than 5 percent. Some of these nitrate-bearing soils are used directly as manures, but most are used for the extraction of saltpetre. To the collected nitrate-bearing earths (*lona matti*) wood ashes are added in order to decompose any calcium nitrate which may be present, and the salts are dissolved in water. The liquor contains approximately 15·25 percent sodium chloride, 7·24 percent potassium nitrate and the rest comprises small quantities of chlorides and sulphates. On evaporation of the liquor sodium chloride separates out first, and the nitrate later. The crude saltpetre (*kuthea*) varies widely in composition; it may contain up to 66 percent potassium nitrate and up to 35 percent sodium chloride with some sodium sulphate and magnesium nitrate (6). The crude saltpetre is sometimes used as fertiliser, but most is sent to refineries for the manufacture of gunpowder, a by-product being sodium sulphate. Table 2 shows the amounts of saltpetre produced in Bihar during recent years. Practically all of this comes from Muzaffarpur, Saran, Champaran, and Darbhanga districts, but a small amount is produced in Shahabad, Gaya, Monghyr and Patna.

Pascoe (8, p. 9) has suggested that the production of saltpetre could be increased by the proper organisation of the industry and by the use of artificial drainage traps.

Sodium salts.

The main areas in North Bihar producing sodium salts are Champaran, Muzaffarpur and Saran. Sodium sulphate is also obtained south of Nawada in Gaya and at Sheikpura in Monghyr. The efflorescence, known locally as *reh,* is a mixture of sodium carbonate (*saji matti*), sodium sulphate (*khari* or Glauber's salt) and sodium chloride (common salt). The crude material is treated in a similar way to that used in the extraction of nitrate. A typical sample of *saji matti* on sale in Calcutta contains 27 percent sodium carbonate, 4·28 percent sodium bicarbonate and about 34 percent sodium sulphate. No statistics are now available of the production of these salts from Bihar, but in the fourteen years 1908-1923 the out turn was 207,851 tons of *khari.*

Future.

Although alkali salts will continue to be extracted from the surface soils in North Bihar for local use, there does not seem to be much possibility of any great expansion of the industry, in view of competition from imported salts.

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CHAPTER IX.

APATITE.

General.

In Bihar, apatite is found as veins in Singhbhum. It also occurs in some of the mica-bearing pegmatites of the mica belt, in Gaya, Hazaribagh and Monghyr districts. Sir Thomas Holland suggested some 40 years ago that the mineral might be recovered from the waste heaps at the mica mines by washing and picking, but later experience clearly indicates that the mineral occurs in amounts much too small for such recovery to be ever economically practicable. Apatite also occurs as an important constituent of the mica-peridotites of the coalfields, but the calcium phosphate content of these ranges between 4·5 and 12·5 percent of the rock, hence the grade is much too low to be of any economic value.

Uses.

Phosphates are invaluable as fertilizers. In the past, ground apatite from Singhbhum has been used for this purpose. Apatite is, however, very stable, but by converting the mineral into super-phosphate after treatment with sulphuric acid its available phosphate for fertilizing can be considerably increased.

At one time apatite-magnetite-rock from Singhbhum was added to the blast furnace charge in the Bengal Iron and Steel Company's works at Kulti for the smelting of phosphoric pig-iron, which, on account of its high fluidity, is particularly useful for foundry purposes.

Apatite in Singhbhum.

The apatite deposits which occur in Dhalbhum subdivision, Singhbhum, have been known for many years. The mineral is found along a belt extending southeast from the Saraikela State eastern border (22° 45′ : 86° 06′) to Khejurdari (22° 24′ : 86° 34′), a distance of about 40 miles. Iron-oxide, magnetite, is associated in places and the southern part of the belt, between Patharghara (22° 32′ : 86° 27′) and Khejurdari, was leased at one time to the Bengal Iron and Steel Co. for phosphoric iron-ore. During the war, 1914-18, the Great Indian Phosphate Co. worked the deposits

at Badia (22° 29′ : 86° 28′), Kanyaluka (22° 29′ : 86° 31′) and Sunrgi (22° 27′ : 86° 33′), but this company went into liquidation and the lease was transferred to a private syndicate. Mining in this southern section ceased in 1925.

At the northwestern end of the belt, around Nandup (22° 44′ : 86° 12′), Mr. E. O. Murray mined apatite for several years following the close of the war in 1918. For the period 1924-28, 14,700 tons of apatite were supplied for agricultural purposes and to the iron trade, but the demand then gradually ceased owing to the importation of higher grade phosphate for fertilizers from Egypt and Algeria and also to the abandonment of the use of apatite by the iron trade.

During 1928-30, the Tata Iron and Steel Company took options on the leases of the whole belt. The deposits were prospected by a very extensive series of trenches and pits. The options have not been exercised.

Within the last two or three years enquiries for apatite have been again made for various purposes and there has been a certain small production.

Mode of occurrence.

The apatite deposits occur as veins in the schists, particularly in granite-schist. They are associated with and strike parallel to the copper lodes, and belong to the same general period of mineralisation as the latter.

The mineral is usually fine-grained, but larger-sized crystals up to two inches diameter may be occasionally found in relatively pure parts of the veins. The coarse apatite may be white in colour, but the fine apatite is pale buff; owing to the presence of chlorite the apatite-rock is more commonly greenish and, where magnetite is present, it may be black. In addition, biotite and quartz are present in places. All of these minerals occur in variable proportions, pure apatite veins are rare and the great majority are of apatite and chlorite or biotite, with varying amounts of magnetite. In some veins near Patharghara the proportion of magnetite is very high, with partial exclusion of apatite and almost total exclusion of biotite and chlorite.

The veins vary in thickness from a fraction of an inch to as much as 60 feet. In length they vary considerably, the longest so far worked being at least 900 feet. The depth to which they extend is unknown, but there is no reason to assume that they

will be restricted to the surface. From the point of view of mining, their depth will be determined by the economic limit to which the working of the more persistent veins can be taken.

The percentage of P_2O_5 present in the vein material varies according to the amount of other minerals present. Material assaying 35 percent P_2O_5 has been obtained, but the workable apatite averages 20-25 percent P_2O_5. By magnetic separation, for the removal of magnetite, the grade can be readily improved. An analysis of typical vein material from Chandar Buru (22° 43′ : 86° 13′) is given in Table 3.

TABLE 3.—*Analysis of apatite, Singhbhum.*

	Percent.
SiO_2	10·12
Al_2O_3	24·42
Fe_2O_3	15·18
CaO	19·93
MgO	3·24
P_2O_5	20·10
K_2O	0·18
Na_2O	0·76
H_2O+	4·09
H_2O-	0·98
Cl	0·02
F	0·73
TOTAL	100·05
Less O for F	·30
	99·75

Localities.

The apatite belt may be divided into three main sections: (*a*) around Nandup, from the Saraikela border to Chandar Buru, (*b*) around Patharghara, and (*c*) from Badia to Sunrgi and Khejurdari. In general the apatite near Chandar Buru represents an average apatite-chlorite-magnetite-rock; at Patharghara it is particularly high in iron, grading to iron-ore; the apatite at Badia is similar to the Chandar Buru rock, perhaps coarser grained; whilst some of the veins at Sunrgi supply a white apatite free from magnetite and chlorite.

The minimum known reserves in these three main localities down to a depth of 100 feet, are :—

Around Nandup, 250,000 tons, averaging 20 to 25 percent P_2O_5.

Patharghara, 250,000 tons.

Badia, Kanyaluka and Sunrgi, 100,000—200,000 tons, averaging 20 to 25 percent P_2O_5.

The section around Nandup is probably the most important. Not only do the deposits here occur as large veins, but they are also convenient to the railway which here cuts across the belt. The largest group of veins occurs to the northeast of Chandar Buru, where at one point apatite, with schist partings, occupies a width of 60 feet. Another vein at the southern foot of the hill has been worked over a length of 300 yards with a width of up to 10 feet. Most of the veins dip at 45° to the north. Frequently they are arranged *en echelon*.

Around Patharghara the veins are up to 20 feet in thickness, but none appear to be more than about 200 feet in length. They were all mined by shallow open cut, the quarries being now filled with water. The granite and mica-schists in this vicinity seem to be riddled with apatite-magnetite veins.

Apatite veins are well developed in the mica-schist and granite-schist east of Badia and south of Bhadua (22° 28′ : 86° 30′), but they are not so persistent as at Nandup. Sometimes irregular rounded masses of pure coarse apatite, two feet across, are found as segregations in the schists.

At Kanyaluka (22° 29′ : 86° 31′) the apatite veins are small and occur in chloritic biotite-schists and hornblende-schists.

Up to 1925 quite a considerable but widely fluctuating production of apatite was obtained from Sunrgi; in the last two years before closing down in 1925, 3,406 tons was mined in 1923-24 and 2,273 tons in 1924-25. The country-rock is chloritic and biotite-schists, but these are penetrated by innumerable veins of mylonised granite. Some of the apatite veins here are perhaps the purest in the belt, yielding a white apatite free from magnetite and chlorite.

Future development.

There is room for considerable research on the utilisation of the Singhbhum phosphate deposits, not only as fertiliser and in the

iron and steel industry, but also in other industries where phosphates may be of use. For use as a fertiliser the calcium phosphate should be converted into a more soluble form, to render it readily available to plant life.

In view of the nature of the occurrence it is unlikely that the apatite could be mined and treated sufficiently cheaply to be extensively used as fertiliser. Its principal use is likely to be in the iron and steel industry or in other industries where limited quantities of phosphate are required.

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CHAPTER X.

ASBESTOS.

The main uses for asbestos are as follows: in asbestos textiles as yarns, cordage and cloth, in paper, compressed sheets, blocks and brake linings, in such cement products as shingles and corrugated sheets, in heat-resisting articles, in pipe and boiler lagging, in jointing materials, in paints and roofing cements, and for filtering, packing, etc.

There are two main varieties of asbestos used in industry: chrysotile ($3MgO.2SiO_2.2H_2O$) and amphibole asbestos. A variety of the latter found in India is tremolite ($CaO.3MgO.4SiO_2$). It is the physical properties of asbestos that are important: flexibility and fineness of fibre. length of fibre, tensile strength, fire and acid-resisting and heat-insulating qualities. As a general rule chrysotile is more flexible than the tremolitic variety of asbestos. Simple field tests may be made by teasing the mineral fibres apart and rolling between the fingers, good asbestos separating into fine silky elastic fibres which may be bent repeatedly and sharply over the thumbnail without breaking.

Although length of fibre is desirable for spinning for the manufacture of asbestos textiles. short fibre material has a wide use for other purposes, and, even for spinning, short fibre material down to $\frac{3}{8}$-inch can be used. Asbestos is graded for marketing according to the length of fibre, the best grades being $\frac{3}{4}$-inch.

Asbestos has been prospected near the following places: Manpur (22° 36′ : 86° 16′), Digarsai (22° 35′ : 86° 15′) Lipokocha (22° 25′ : 86° 30′), Mahespur (22° 23′ : 86° 30′), Chirutanri (22° 24′ : 86° 34′) in Dhalbhum and from Mahulbasa (22° 51′ : 86° 19′) in Manbhum (1). Although each of these deposits apparently yielded a small amount, all the asbestos near the surface has been removed and it is not economically possible to prospect at depth. These deposits were found to be of tremolitic asbestos, although the chrysotile variety has also been reported—this seems very probable as, in places, the material is very flexible. In the neighbouring State of Saraikela quite large logs of rather brittle tremolitic asbestos, up to 14 feet long, have been mined at Bara Bana (22° 37′ : 85° 56′). All of these deposits are associated with basic and ultrabasic igneous rocks, more especially where the latter have been altered to serpentine.

Fermor has noted that chrysotile asbestos is associated with serpentine where the latter is exposed by chromite quarries in the Sahedba and Anjedbera Forests west of Chaibasa, in the Kolhan (2). As in Dhalbhum, the quantity is insignificant. Jones has also found thin veins of tremolite in ultrabasic rocks further south, at Tonto (22° 23′ : 85° 37′) and Nurda (22° 20′ : 85° 44′) (3).

Samples of poor quality asbestos, reported to have been found near Itakeel (Itki, 23° 21′ : 85° 08′) in Ranchi district (4), were brought to the office of the Geological Survey in 1912 by Mr. K. M. Pandin. Sherwill recorded two occurrences of asbestos in Monghyr district, one consisting of thin veins in slates on the Goria Koh *ghat* (? Ghorakhor Hill, 25° 12′ : 86° 31′) (5, p. 197), and the other of massive asbestos near the summit of Pirpahar Hill (25° 23′ : 86° 31′), three miles east of Monghyr (5, p. 204). These were probably incorrect identifications.

Further prospecting, particularly in the area covered by the intrusive ultrabasic rocks of Dhalbhum, may bring to light more deposits, but the experience of the past is by no means favourable.

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CHAPTER XI.

BARYTES.

Although the occurrence of barytes, a barium sulphate, has been known in Bihar for many years there has been little active production of the mineral.

Most of the world's production of barytes is used in the manufacture of lithopone, which is the basis of many paints, and it is used also in the manufacture of motor tyres and other rubber goods. It is also used as a filler in the paper, cloth and linoleum industries, and it is a constituent of some types of glass, enamels and glazes. Other uses are as a source of barium chemicals and even as a furnace lining. Perhaps its principal use in India is as a white pigment and inert extender. Quite a considerable amount of barytes is used in India and Burma for weighting the mud-fluid in rotary drilling on the oilfields; the mineral's high specific gravity makes it suitable for this purpose.

A specimen of barytes, said to have come from Bramjan Hill (probably the Gaya Brahmjoni temple hill) near Gaya, was brought to the office of the Geological Survey of India in December, 1923.

A series of veins of barytes occur in the granite-gneiss some 14 miles east of Ranchi, striking more or less east and west through the following villages: Silwai (23° 22′ : 85° 26′), Bahea (23° 23′ : 85° 29′) and Bongabera (23° 21′ : 85° 31′). A little galena is also associated, and it is probably for this reason that the deposits have not been exploited for paint manufacture.

Specimens of barytes from Manbhum have been submitted to the Geological Survey from time to time in recent years (3). Most of these come from near Purulia, apparently from the village Malthol (23° 26′ : 86° 26′) on the Panchhot Raj Estate. Some of these specimens have been of excellent quality, others have been associated with apatite, allanite, galena, bismuthinite and bismutosphaerite. The field occurrences of these specimens have not been examined by the Geological Survey, but they appear to warrant some investigation.

Dr. Krishnan of the Geological Survey of India, has recorded the presence of veins of barytes in the sericite-schists about half a mile to the southwest of Kolpotka (22° 22′ : 85° 06′) in Singhbhum,

close to the Gangpur border (1). These veins are grouped in two zones. In the southern zone the veins occur within an area 300 yards by 150 yards, and were worked in 1927 by open cut. 2 to $2\frac{1}{2}$ tons being obtained per day. Barytes formed only 5 to 7 percent of the material extracted. The northern zone of veins was too poor to be profitably worked.

Although specimens of barytes, said to have come from near Ghatsila (22° 35′ : 86° 29′), have been shown to the author the exact locality has never been found.

It will be apparent from the above information that a barytes industry in Bihar is never likely to be other than small. Still, there does appear to be room for a more energetic investigation of what barytes deposits there are, with a view to determining whether some small local industry of a specialised nature, such as the extraction of barium salts in which only a small annual tonnage would be required, could be developed in the province.

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CHAPTER XII.

BAUXITE.

General.

The name bauxite was given to a peculiar clayey substance which contains a very high percentage of alumina and water, some ferric hydroxide and a comparatively small percentage of silica and other impurities. In India it is a variety of laterite relatively free from ferric hydroxide.

Bauxite has been found in many parts of India, associated with the widespread laterites, particularly those which cap the Deccan trap. In Bihar, they have been found on several of the small plateaux which rise to a height of 3,000 feet in western Chota Nagpur.

There has been a certain small annual production of bauxite in India, but for various reasons the utilisation of the excellent deposits in Bihar has, until recently, been almost entirely neglected. An alumina works and aluminium reduction plant was in course of erection near the Damodar river southeast of Asansol at the outbreak of the war in 1939, but owing to most of the machinery having been on order from Czechoslovakia the plant had not arrived. Another similar alumina and aluminium works was to have been erected in the South Karanpura coalfield, but this project was dropped in favour of a scheme in South India. As matters stand at present there is a hope that an alumina works will be erected in one or other of the coalfields in Bihar as a war measure, but no aluminium reduction works so far as can be judged at present.

Uses.

The industrial applications of bauxite are manifold. Perhaps its most important use is as a source of the metal aluminium. The ores available in Bihar are sufficiently high grade for this purpose, but until recently the deterrent to the manufacture of aluminium in this country has been the lack of readily available supplies of cryolite, which is required in the process of reduction, and also the necessity of obtaining a cheap supply of power. Although cryolite could be imported, now that calcium fluoride (fluorite) is available in the Central Provinces it may eventually be possible to produce artificial cryolite in India.

Bauxite can be manufactured into a high-quality refractory brick for furnace linings, and it is also the raw material for the manufacture of certain alumina abrasives which are used as grinding powders or made into grinding wheels, etc. It is also now widely used in the manufacture of aluminium sulphate and other aluminous salts. Certain commercial products, known as "alumino-ferrite" and "alferite", are prepared by digesting crude bauxite with sulphuric acid and are used in the preparation of all but the finest papers, in the precipitation of sewage and refuse liquids, and in the clarification and decolarisation of water supplies. The aluminium salts are directly used in the chemical industries of dyeing, tanning, and printing. Aluminium chloride has been recommended for the preservation of wood, whilst an impure chloride containing also calcium and sodium salts is a disinfectant. The quick-setting properties of alumina cement, *ciment fondu*, have long been known; experiments have recently been made in India for the preparation of alumina cement from local bauxite and limestone. Most of the bauxite produced in India, to date, has been used by the oil companies for the purification of kerosene.

Classification.

For commercial purposes bauxites may be classified into the following varieties:

(*a*) Normal bauxite. High-grade ore with over 60 percent alumina, and fair quality ore with 55 to 60 percent alumina. Excluding combined water, total impurities should not exceed 20 percent. The chief impurities, ferric oxide, silica and titania, each should not exceed 5 percent.

(*b*) White or siliceous bauxite. Contains upwards of 55 percent alumina, and not more than 20 percent impurities excluding combined water. Silica from over 5 to about 20 percent. Ferric oxide less than 5 percent. Titania up to 5 percent. This class of ore is most frequently used for chemical purposes, and the preparation of alum or other aluminium salts.

(*c*) Titaniferous bauxite. The alumina should average 55 percent and the total impurities, excluding combined water, should not exceed 25 percent. Titania above 7

percent. Silica less than 5 percent. Ferric oxide should not exceed 10 percent. These bauxites are rare except in India. but should prove valuable because of their titania content which it may be possible to collect as a by-product if the Bayer process is used for treatment of the ore.

(*d*) Ferruginous bauxite. Alumina content should be near 52 percent, and total impurities not greater than 25 percent. Ferric oxide between 10 and 25 percent. Silica less than 5 percent. Titania normally less than 5 percent. This variety of bauxite is that generally used for reduction to aluminium.

Some analysis of typical bauxites from Bihar are given in Table 4.

TABLE 4.—*Analyses of Bihar bauxites.*

—	1	2	3	4	5	6
	Percent	Percent	Percent	Percent	Percent	Percent
SiO_2 . .	1·79	0·18	0·16	1·54	0·10	0·30
TiO_2 . .	3·30	12·02	13·81	8·70	16·12	7·40
Al_2O_3 . .	64·64	51·69	52·45	62·00	52·43	66·98
Fe_2O_3 . .	6·21	5·52	8·68	5·99	7 89	5·92
CaO . .	0·04	..	..	..	..	..
MgO . .	0·02	0·78	1·28	..	2 20	trace.
H_2O+ . .	24·00	29·92	23·94	21·96	?1·80	21·40

1. Netarhat, analysis by Dr. Warth.
2. Khamar Pat, 10 miles north of Lohardaga, Ranchi district.
3. Bagru Pat, 6 miles W. N. W. of Lohardaga, Ranchi district.
4. Dudha Pat, 10 miles W. of Lohardaga, Ranchi district.
5. East of Serendag (23° 22′ : 84° 29′), Ranchi district.
6. Rajadera (23° 17′ : 84° 14′), Ranchi district.

Localities.

A detailed account of the bauxite occurrences in Bihar is given by Fox (2, pp. 164-183), of which the following is a summary.

The bauxite deposits are confined to the edges of the scarps bounding the laterite-capped plateaux in western Chota Nagpur, in Palamau and Ranchi districts.

In Palamau, small deposits of bauxite have been found on Jamira Pat, west of Mahuadand (23° 24′ : 84° 07′), and Netarhat.

The important deposits are in Ranchi district. The largest plateau is that of Serendag (23° 22′ : 84° 28′) which may be divided into four distinct areas and around which there is a minimum of 440,000 tons of bauxite, with also, in places, some clay deposits.

Possibly the best deposits are on Bagru Pat (23° 29′ : 84° 36′) where there is a minimum of 500,000 tons associated with which there are excellent clays which have some of the properties of fuller's earth.

On Dudha Pat (23° 25′ : 84° 30′) there are at least 250,000 tons, on Kutcha Pat (23° 11′ : 84° 20′) 100,000 tons, on Khamar Pat (23° 37′ : 84° 41′) 60,000 tons, and on Banjari Pat (23° 22′ : 84° 30′) 50,000 tons. Considerable but unknown tonnages occur on Pakhar Pat (23° 34′ : 84° 37′), Chapuadhia Pat (23° 28′ : 84° 34′), and on Pakri Pat near Rajadera (23° 17′ : 84° 16′). Small deposits are known to occur on Oronga Pat (23° 36′ : 84° 38′), Banda Pat (23° 22′ ; 84° 32′), and Bar Pat (23° 17′ : 84° 26′), but in the absence of detailed prospecting little can be said about them.

Indications of the occurrence of bauxite have been found on a number of other small plateaux in this area, and it would appear that the total amounts of bauxite which will eventually be found available, when mining is undertaken, will prove to be many times the above-quoted quantities.

Very recently deposits of aluminous laterite, approaching bauxite, have been found in the Kharagpur hills, Monghyr district, on Maruk hill (25° 11′ : 86° 28′), Maira hill (25° 14′ : 86° 32′) and Khapra hill (25° 10′ : 86° 27′).

Mode of occurrence.

The caps of the high plateaux in western Chota Nagpur are outliers of Deccan trap which represent the denuded remains of an original continuous sheet, and represent a very old land-surface now almost completely removed. These traps have been subjected to sub-aerial alteration over a prolonged period of time and this alteration, in a tropical climate of alternating wet and dry seasons such as in India, has resulted in the formation of laterite, a hydrated oxide of iron and alumina, the greater portion of silica and other constituents, apart from titania, having been removed in solution.

The rocks thus become covered by a layer of laterite, which, in the plateaux of western Chota Nagpur, probably averages 30 feet in thickness but may vary considerably, depending on local contour and rock variations around and on the plateaux.

On studying sections across these plateaux, it is found that certain well defined layers may be distinguished between the surface and the unaltered rock below. At the surface there is generally a thin layer of red or yellow clay, but this is absent in many places, particularly around the scarp-edges of the plateaux, and the underlying layer of hard ferruginous laterite is commonly exposed. This layer may be of variable thickness, but 1 to 8 feet is most usual. Along the scarp-edges of the plateaux this hard laterite is typically pisolitic in structure. Immediately below this hard layer of ferruginous laterite there is a layer of bauxite varying considerably in thickness, usually from 8 to 24 feet, but always thickest at the edges of the plateaux scarps or below any stream depressions in the plateaux surfaces, and completely thinning out laterally towards the centres or higher parts of the plateaux. At the extreme edges of the plateaux, along the scarps, the bauxite, like the ferruginous laterite, is commonly pisolitic in structure. Below the bauxite and immediately below the hard laterite in the centres of the plateaux, there is a zone of soft porous laterite, generally 12 to 30 feet in thickness and extending down to groundwater level. Underlying this is a zone of laminated siliceous lithomarge, from 6 to 20 feet in thickness and in places forming a useful clay. This overlies kaolinised trap, which may be 40 to 60 feet in thickness before the unaltered trap is entered.

This orderly arrangement is the result of unchanging conditions of rock alteration, drainage, and seasonal sequence over a prolonged period of time. Below groundwater level kaolinisation of the rocks is taking place. Above groundwater level the more soluble constituents, such as silica, are carried downwards either in solution or as colloids, leaving this zone higher in alumina. The iron hydroxide is either drawn to the surface by capillarity during alternating dry seasons, or remains in the lower part of the zone, so that between the two layers of laterite the zone becomes impoverished in iron, and increasingly rich in alumina. The alumina itself forms a gel which separates out on the outer scarp face of the leached bauxite layer as pisolitic bauxite. The actual chemical processes involved form a difficult and perhaps, as yet, uncertain study.

Future.

There is no doubt that the bauxite deposits of Bihar will be a valuable asset in the future. Although information as to their distribution is well enough known, there is no exact knowledge of the actual reserves available. However, the minimum reserves calculated in some of the localities are sufficient to warrant the establishment of industries to utilise this bauxite, and it can be safely left to the companies concerned to determine their own reserves.

Further prospecting in these western plateaux will undoubtedly bring to light new deposits of bauxite. It is doubtful whether prospecting of the laterite in other parts of Bihar will result in finding bauxite deposits elsewhere, but it is certain that high alumina laterites would be found which could be used for certain purposes.

The actual development within the province of industries based on these bauxites should be encouraged. All the facilities of coal supply and cheap power are available.

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CHAPTER XIII.

BUILDING MATERIALS.

General.

Bihar is particularly fortunate in the many different varieties of rock which are available not only for construction of buildings but also for diverse civil engineering purposes. These materials range from alluvial clays for brick making, sands for mortar and cement-concrete, and gravels for road metal, concrete and railway ballast, to various types of building stones, roofing slates, ornamental stones, and limestones for the manufacture of cement.

In general the production of building materials in Bihar is of local importance. Adjacent provinces to the west possess equal resources of this nature. Bengal is not so fortunate, and a certain amount of building material does find its way into that province from Bihar, but in some cases there is competition with cheaply transported sea-borne material imported into Calcutta.

Expansion of the trade in building materials in Bihar is certain to continue with development of civil engineering and building construction in the future, and there is little question that the province's resources will be well able to take care of all that may be required.

Building clays.

The sources of clays for brick-making purposes are indicated in Chapter XV. They are widely distributed; most are alluvial deposit which vary in suitability, and, although generally of a sandy nature producing bricks of poor quality, there is no dearth of material suitable for the manufacture of the best quality bricks. The same may also be said of clays used for the manufacture of roofing tiles. Clays are also required for the manufacture of cement. At one time the Sone Valley Portland Cement Co. obtained its clays for this purpose from the Gondwana clay beds near Daltonganj, but local alluvial clays close to the works at Japla are now used for this purpose.

In Bihar there is scope for some research on the suitability of the various clay deposits for the manufacture of bricks and tiles of various types.

Building stones.

Granite and granite-gneiss.—Granite and granite-gneiss are widely distributed throughout Chota Nagpur, but, presumably because these rocks are difficult to work, they are not quarried for building purposes although they are much used for road construction. These granitic rocks would undoubtedly form a most pleasing building stone and some of the curiously banded and figured granite-gneisses could even be used for ornamental purposes. Because of their hardness, quarrying and dressing of these rocks would be more expensive than in the case of sandstones.

Laterite.—Laterite has been used for building construction to a certain extent in Singhbhum and Manbhum close to deposits of the material. It is very easily quarried and worked, and rapidly hardens on exposure. Just over the border from Bihar, in Bengal, it is used very extensively in such places as Kharagpur where there is a thick surface layer of laterite. It is a very cheap form of building material but, if unrelieved by any other rock, it has rather a monotonous appearance.

Sandstones and quartzites.—Sandstones suitable as building stones occur in various geological formations and in various districts in the province.

Sandstones and sandstone-quartzites of the Iron-ore Series in Singhbhum are quarried for local building purposes, particularly near Barijol (22° 34′ : 85° 51′), northeast of Chaibasa and northwest of Galudih station (22° 39′ : 86° 25′). They provide an easily worked stone, usually of a light grey or pale-buff colour of quite pleasing appearance, some having a slightly greenish tint. They all weather very well and can be used in the most exposed positions. The harder stones could take quite a good polish, but as a rule they are used rough-dressed. Some of the conglomerates which are found with these sandstone-quartzites would make a most attractive building stone, but would be difficult to work. Similar Archean sandstone-quartzites in Monghyr and Gaya districts are equally suitable for building purposes. The quartzites east of Dharhara station (25° 15′ : 86° 24′) are cut into blocks by contractors and sold to the B. and N. W. Railway. The usual rate is about Rs. 32 per 1,000 cu. feet.

The basal sandstone of the Kolhan Series in Singhbhum has been quite extensively quarried for building purposes in Chaibasa. It is a finely banded, well-bedded and easily worked stone of dark

purplish colour. Although for the most part it is rather soft it is quite resistant to weathering and retains its rather sombre colour indefinitely in any exposed position. For some local buildings in Chaibasa it is used with the light grey Iron-ore Series sandstone-quartzites, which relieve its sombre tone.

Excellent fine-grained sandstones are available in the Vindhyan rocks of the Kaimur hills in Shahabad district. These provide perhaps the best building stones in the province. They occur in massive beds permitting the extraction of quite large blocks. Their colour is generally pale red to grey, some are banded or mottled, and sandstones from the continuation of the same beds over the border in the United Provinces, near Chunar and Mirzapur, have retained their colour even in the most exposed positions throughout the centuries, in such Moghul buildings as at Fatehpur Sikri, Agra, Delhi and Benares.

Gondwana sandstones have been used on the coalfields for building purposes. Sandstones of Talchir age from the Bokaro coalfield have been used for building purposes and as paving stones in Hazaribagh. Sandstones of both the Raniganj and Barakar stages have been used in the vicinity of the Raniganj coalfield and the Jharia field. These are usually fairly soft, medium to coarse-grained, often rather felspathic, and of grey or pale buff colour. They are not, perhaps, so pleasing as the Vindhyan or Archean sandstones, but they are very cheaply worked.

Slate.—Within the Archean sedimentary rocks of the province slates are common enough, but they are usually too soft and brittle to be of value for building purposes. However, slate of good quality is quarried in the Kharagpur hills in the neighbourhood of Dharhara station, Monghyr, and is used for roofing, flooring, electrical purposes and children's slates. A certain amount of slate quarrying has been carried out also in Singhbhum, to the south-east of Bhitar Dari (22° 41′ : 86° 11′), and near Buhuta (22° 34′ : 85° 44′).

Trap.—Trap from the Rajmahal hills was formerly used in temples and forts, but its dark-grey colour is by itself scarcely conducive to inspired architecture on modern standards. However, with careful selection and blending with other building stones, it may still find a wide use in building construction. Large quantities of trap from these hills are used in Bihar and Bengal as road metal.

Ornamental stones.

As yet the stones which might be suitable for ornamental purposes are practically undeveloped. One reason for this is, perhaps, the fact that ornamental stones may be imported fairly cheaply from overseas through Calcutta, but the main reason has probably been that it is not customary in the province to spend money on purely ornamental stones for building construction. However, if a demand should arise for material of this nature, there are several rock-types which might be investigated.

Banded-quartzites.—Banded-quartzites occur in the Archean sedimentary rocks of the province, especially in Singhbhum. Some of these rocks are very finely banded, and in many the bands are delicately contorted into close folds. The best of these rocks are probably the banded-hematite-quartzites of South Singhbhum, which consist of thin alternating dark, pale red, and white layers. These rocks are extremely hard but take a high polish, and, for certain limited purposes, would provide an ornamental stone of unusual but striking appearance.

Epidosite.—Outcrops of beautifully tinted yellow-green epidosite occur in South Ranchi, northwest of Dasauri (22° 56′ : 85° 37′) and south of Rugudih (22° 53′ : 85° 39′), and in South Manbhum, north of Sekradih (22° 54′ : 85° 50′). South of Jate (22° 55′ : 85° 16′) in Ranchi district, the rock is finely banded. These rocks could be used for ornamental purposes, such as for panels. The localities in which they occur are not, however, very accessible.

Granite-gneiss.—Some of the granite-gneisses which occur in Chota Nagpur are so beautifully figured that they could be used for ornamental purposes, such as for wall-panelling, stairways, architraves and lintels. They would be susceptible to a high polish.

Marble.—Within the granitic rocks, and extending as a belt from the western end of the Bokaro coalfield to southwest of Daltonganj, there are a series of outcrops of crystalline limestones and marbles. These are being quarried for use in cement manufacture and in the iron and steel industry, but occasional patches have a purity and quality of colour suitable for ornamental work or even statuary.

Rose quartz.—Associated with many of the pegmatites of the mica belt there is abundant rose quartz. This varies from pale pink to rose colour and is translucent. On polishing, the rock takes on a most pleasing depth of texture and it would be very

suitable for small panels or carved ornaments. At present the rock is being thrown away on the dump heaps. It is particularly abundant in the mines northeast of Parsabad station, and, if care were exercised in mining, quite large pieces could be extracted.

Serpentine.—Associated with the Archean ultrabasic igneous rocks, which are found in parts of Chota Nagpur, there are occurrences of serpentine. In Singhbhum these are found not only in the vicinity of the chromite deposits west of Chaibasa, but also almost everywhere that ultrabasic rocks are known to crop out, and are particularly widespread in Dhalbhum. No attempt has ever been made to open up these serpentines to determine whether they would be suitable for ornamental purposes, but presumably, if a demand should ever arise, they would be investigated.

Soapstone.—In many parts of Chota Nagpur soapstones have been quarried (*see* Chapter XXXII) for use as household utensils. Many of these rocks are greyish green in colour, are pleasantly figured, and easily carved and polished. They could be used extensively for ornamental purposes if the demand should ever arise.

Lime and cement.

The uses and occurrences of limestone in Bihar are described in Chapter XXIII. For the building industry limestone is manufactured into lime and cement; in Bihar the rock is not applied directly as a building stone, although some of the purer marbles could, perhaps, be used for that purpose.

The principal deposits occur at the edge of the Kaimur hills near Rohtasgarh in Shahabad district. Other deposits are scattered within a belt extending west from the western end of the Bokaro coalfield to southwest of Daltonganj.

Another widespread source of lime in Bihar is *kankar*, which is found scattered not only over the surface in alluvial areas but also over soil covering granite, basic igneous rocks, and sedimentary rocks. The *kankar* is formed by the segregation of calcareous material into irregular lumps. With these calcareous concretions a certain amount of argillaceous matter is included, and the proportion of this in many cases is such that, on burning, the *kankar* produces almost a hydraulic lime or "natural cement".

Road metal.

In the extensive alluvial tract north of the Ganges rocks are absent; material for making roads has to be brought from a

considerable distance and is expensive. To the south of the Ganges, however, and extending across Chota Nagpur to the southern border of the province, road-making materials are plentiful, and local supplies of reasonably suitable rock-types can be very frequently obtained within the close vicinity of the roads.

Perhaps the most suitable materials for roads carrying heavy traffic are the medium and fine grained basic igneous rocks, which have not suffered weathering or decomposition. These include the traps of the Rajmahal hills, dykes cutting the granite and other rocks in Singhbhum, Manbhum, and other parts of Chota Nagpur, and the extensive lava flows in the Archeans of Singhbhum, Ranchi, and Manbhum. In opening up a quarry on these rocks—or, indeed, on any rock to be used as a road metal—the upper weathered and decomposed surface should be rejected and only the hard fresh rock used.

The quartzites which occur in the Archeans also provide suitable road metal, providing they are hard, dense, and not too coarse grained. Where these quartzites have been recrystallised to a coarse rock of sugary texture, they tend to break up under heavy traffic and wear rapidly. Quartzites of good quality are well distributed in Gaya, Monghyr (Kharagpur hills), Hazaribagh, Manbhum and Ranchi. Their outcrops generally form hill-country and they are easily quarried.

The granites and granite-gneisses can be used for road making, providing the finer-grained, fresh and dense material is selected. The hornblende-granites are normally more suitable than those which contain abundant mica. Coarse porphyritic granites should be avoided, as the large felspar crystals break up rapidly along the cleavages under load. Quartz from quartz veins is sometimes used as road metal. Such veins are widely scattered throughout Chota Nagpur.

For roads carrying lighter traffic, gravel can be obtained almost anywhere over the granite of Chota Nagpur. Laterite also makes a good road surface.

Ballast.

The same materials which are used for road construction, such as trap, dolerite and quartzite, are also suitable for railway ballast. In addition they find a use as aggregate in concrete mixes. The basal Tertiary gravels of Dhalbhum have been quarried for many years close to Dhalbhumgarh station, and have been used as ballast

along the permanent way of the B. N. Rly.; this gravel also provided the aggregate in the concrete for the pier foundations of the new Howrah bridge. A very unusual material was used in the concrete for the construction of the monoliths at King George's dock in Calcutta; this was the slag collected from the dumps left by the ancients around their copper smelters at Roam (22° 38′ : 86° 24′), near Rakha Mines, Dhalbhum.

Sand.

The river sands of Bihar are sufficiently clean in many places to be suitable for use either in plaster, mortar, or concrete.

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CHAPTER XIV.

CHROMITE.

Introduction.

The occurrence of chromite (an oxide of iron and chromium) in Singhbhum was first discovered by Mr. R. Saubolle in 1907. The deposits have been worked almost continuously since 1909, although the annual production has fluctuated widely according to market requirements. The annual production during recent years is given in Table 5.

TABLE 5.—*Production of chromite.*

Year.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1929	3,149	68,440	49,565	8,41,769
1930	5,101	99,222	50,684	8,67,456
1931	2,749	37,269	19,913	3,15,026
1932	7,638	1,08,972	17,865	2,75,675
1933	7,068	1,01,904	15,526	2,23,245
1934	7,010	92,237	21,576	3,10,066
1935	11,397	1.26,514	39,127	4,79,965
1936	7,053	83,899	49,486	6,04,492
1937	7,678	1,07,258	62,307	8,35,589
1938	5,194	99,928	44,149	6.82,502
1939	4,476	1,01.218	49,136	6,35 511

The principal mining companies are the Singhbhum Chromite Co., Ltd., and Tata Iron and Steel Co.

No other workable deposits of chromite are known in Bihar, although a little has been mined from the adjacent detached part of Saraikela State known as Karaikela.

Uses.

The mineral chromite is the only available commercial source of chromium for metallurgical and chemical purposes. Chromite is smelted to form ferrochrome, which is used in the manufacture

of special chrome steels; chromium is one of the main constituents of stainless steels. The metal is widely uses for chromium plating. The mineral chromite is an excellent neutral refractory, withstanding high temperatures, and is manufactured into bricks for furnace linings. Oxides of chromium and chromates of the alkalies are employed as pigments, and in dyeing, calico printing and in tanning.

Chromite from Singhbhum has been used for the manufacture of chromite bricks for refractory purposes, and in the manufacture of chromates.

Grading.

The Singhbhum chrome-ore is selected into three grades, first grade containing over 47 percent Cr_2O_3, second 44-47 percent Cr_2O_3. Low grade chromite is "concentrated" by a primitive process of hand-picking and winnowing which is at the same time wasteful. Presumably a much cleaner product could be obtained by mechanical means with a lower percentage of loss.

The impurity in the Singhbhum chromite is almost entirely serpentine, which forms the matrix between the grains of chromite in the ore.

Occurrence.

In the neighbourhood of Jojohata (22° 31′ : 85° 38′), a village some 11 miles west of Chaibasa, Singhbhum, there are outcrops of ultrabasic igneous rocks forming the hills known as Kimsi Buru, Kitta Buru, Chitung Buru and Roro Buru in the Anjedbera Protected Forest and the Sahedba Reserved Forest. These ultrabasic igneous rocks are peridotites, and include such types as saxonite, and dunite. They have been intruded into the surrounding slates and phyllites, sometimes with the formation of chert along their margins.

The peridotites have been quite widely serpentinised, and grains of chromite are quite abundantly scattered in the serpentinised rock. In addition, well-defined veins of chromite also occur. Although the mineral was a primary constituent of the peridotite, the veins appear to have been formed by the movement of late magmatic liquid along planes of weakness in the peridotite; this liquid not only gave rise to serpentinisation in the peridotite but also deposited chromite along the vein channels.

The veins are lenticular in shape, up to 3 feet thick and 100 feet long. Individually, therefore, the deposits are small, but quite a considerable number of the veins have been exposed.

The veins are worked by small open-cuts, and so far it has not proved economically feasible to undertake deep mining even if these thin veins should prove to continue to any depth.

Specimens containing chromite have been recorded (4) from Hotag hill, Silli (23° 21′ : 85° 50′), in Ranchi district, and from Baida Chauk (24° 46′ : 87° 02′), 5 miles from Mandar Hill station, in Bhagalpur district, but these appear to be merely of mineralogical interest.

Wherever ultrabasic igneous rocks occur in Bihar they are well worth closely prospecting in case chromite is associated with them.

Future.

Although the total reserves of chromite-ore in the Jojohatu area are not known, it is obvious that there are no large deposits and the industry is not capable of any considerable expansion. The jungle is thick in this area and undoubtedly other veins will be found which will permit the industry to continue for a good many years on approximately its present rate of production.

It would appear that, if Bihar is to make the best use of the Singhbhum chromite-ore, it should not be exported as such, but should be manufactured in the province into alkali bichromate or made into ferrochrome. The possibility of its use for the latter purpose should be very closely studied and developed.

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CHAPTER XV.

CLAYS.

General.

Although the working of clay deposits and the manufacture of firebricks forms a very considerable industry in Bihar, there is room for further research on the clays available in the province. Although the clays being utilised at present for the manufacture of firebricks are fairly well known, as also are a few of the more important kaolin deposits, little detailed information is available to the public about many deposits of clays scattered throughout the province, although individual firms presumably have much data. In view of the large clay resources in Bihar the ceramic industry should be capable of great expansion in the future, and china-clays, at present sent out of the province, will undoubtedly be utilised by local pottery works.

Information on clays in Bihar is not only meagre but is also scattered in various publications. Recently, however, two very useful accounts have appeared, one by W. H. Bates and the other by H. Crookshank, and in these most of the available information has been summarised. To any one who should undertake detailed work on Bihar clay deposits a study of the literature listed at the end of this chapter is imperative. The present account can do no more than summarise the available information.

In Bihar an extensive industry has grown up based on the use of the various types of clays. Within the province there are four large manufacturers of refractory clay goods: Bihar Firebrick and Potteries, Ltd., Gulfurbari Firebrick Works, Kumardhubi Fireclay and Silica Works, Ltd., Reliance Firebrick and Pottery Co., Ltd., whilst fireclays are also sent to works in Bengal. Most of the china-clay is sent out of the province, to be used in the paper and textile industries. Statistics of production of china-clays, and refractory and other ceramic clays in the province during recent years are given in Table 6.

Apart from the manufacture of tiles by the Bihar Firebrick and Potteries, Ltd., only firebricks are made by the works in Bihar.

Bihar clays are, however, sent to Bengal for the manufacture of sewer pipes and fittings, sanitary ware, domestic utensils, and roofing

TABLE 6.—*Production of clays.*

Year	BIHAR				INDIA.			
	Production of china-clay		Production of all clays		Production of china-clay		Production of all clays	
	Tons.	Value in rupees	Tons	Value in rupees	Tons	Value in rupees	Tons	Value in rupees.
1929	9,418 (*a*)	1,80,532	27,131	2,67,203	16,657	2,10,251	363,828	3,44,524
1930	9,646 (*a*)	98,639	30,731	1,94,251	19,116	1,29,698	180,319	3,61,830
1931	14,996 (*a*)	1,53,483	22,501	1,87,576	23,365	1,79,890	160,968	3,41,492
1932	9,645 (*a*)	80,939	20,898	1,06,028	13,486	97,442	130,884	2,58,701
1933	10,549 (*a*)	52,951	32,319	1,08,650	21,935	80,656	100,525	2,81,513
1934	11,843 (*a*)	51,159	44,300	1,46,759	21,300	80,317	367,305	3,43,222
1935	7,272 (*a*)	97,878	35,118	1,85,212	14,955	1,30,172	311,049	3,93,557
1936	9,661 (*a*)	86,493	17,524	1,04,098	20,110	1,12,740	318,512	2,93,373
1937	7,407	1,27,091	11,687	1,35,547	17,081	1,57,133	330,007	3,25,578
1938	7,493	1,37,005	19,872	1,58,360	23,937	1,76,633	320,860	3,76,270
1939	11,371	2,38,997	18,361	2,55,159	41,207	3,57,455(*b*)	328,603	5,24,909

(*a*) Includes Orissa.
(*b*) Value of Travancore production not included.

materials of a non-porous nature; china-clays are manufactured into pottery ware, insulators, acid jars, urinals, and wash bowls. Apart from insulators the china-clay and porcelain products of Indian works are not on the whole equal as yet to imported European ware, but the quality is steadily improving.

Uses and classification.

Clays are essential for many purposes, but the principal uses in Bihar are in the manufacture of village pottery, building bricks, cement, firebricks and other refractory articles, ceramic ware, and as a filler in the paper and textile industries. Other minor uses to which clays are put in Bihar are in the manufacture of soap, and for medicinal purposes, colour washing and the modelling of Hindu images.

The more impure clays are suitable only for the village potter, or for the manufacture of bricks for building purposes, and also for the manufacture of cement. Such clays are usually found adjacent to the villages or works.

Clays of better quality, necessary for the firebrick, ceramic, paper and textile industries, may be divided into varieties from the industrial point of view: (*a*) refractory clays, used for the manufacture of firebricks and other refractory articles, and (*b*) non-refractory clays, used in the ceramic and other industries. Such clays are of three types—sedimentary clays, kaolins or clays derived from the decomposition of felspar *in situ*, and lithomarges or clays which are found immediately underlying laterite.

The best quality clays, which can be used for the manufacture of high-grade white ceramic goods, or are white in colour and can be used in paper and textile industries, are known as china-clays. The majority of such clays are kaolins, but it by no means follows that all kaolins can be used for these purposes, as staining destroys the value of many. All true kaolins are highly refractory, but only the poorest qualities are used for making refractory materials. Certain sedimentary clays are sufficiently pure and white in colour to be used as china-clays. The prices which china-clays command, particularly those of good quality, are far higher than those for other clays.

Occurrence.

Potter's clay.—The village potter uses suitable earths adjacent to his village for the manufacture of roofing tiles, domestic utensils and local brickmaking. These earths are either the decomposition products of the rocks *in situ* or are sediments deposited along river valleys, and are very impure. They naturally vary enormously in quality from place to place, giving rise to fired products of different colour, porosity and strength; the pottery manufactured in certain localities acquires a reputation for particular purposes owing to some peculiarity in property. In view of the widespread distribution of the potter's clays, any survey of them throughout the province would be a special undertaking.

Brick clays.—Clays suitable for brickmaking may be very impure; they are widely distributed in Bihar, and are obtained as surface earths, and from the recent alluvium of the Gangetic plains or along river valleys. It is possible to manufacture bricks almost

anywhere in the province from clays adjacent to building sites. Such bricks vary widely in quality, but usually the standard required in this part of India is not high. On the whole, the greater the plasticity of the clay the better is the quality of the brick. The poorness of many bricks used in the province is a consequence of the very sandy nature of many of the clays used. In view of the widespread nature of this material, brickmaking clays need not be discussed further.

Fireclays.—The great majority of the refractory clays in Bihar occur as beds associated with the coal-seams in the Gondwana rocks. The best clays occur more particularly in the Barakar series, but they are found also in the Raniganj series. The fireclays from this source are made into refractories which are equal to the best of other countries. The Gondwana clays are used also for the manufacture of ceramic ware. Some analyses of these clays are given in Table 7.

TABLE 7.—*Analyses of Bihar fireclays.*

—	1	2	3	4	5	6
	Percent	Percent	Percent	Percent	Percent	Percent
SiO_2 . .	44·70	49·96	63·08	53·58	54·43	60·02
Al_2O_3 . .	38·08	34·44	33·42	30·88	30·77	27·65
$FeO+Fe_2O_3$.	1·20	1·00	0·50	0·68	0·77	1·20
TiO_2 . .	1·96	1·62	2·00	..	1·36	1·40
MgO . .	tr.	tr.	0·20	0·22	0·35	0·33
CaO . .	tr.	0·22	0·11	0·28	0·20	..
Na_2O . .	0·14	..	..	0·25	0·36	0·12
K_2O . .	0·76	..	..	1·15		
H_2O . .	13·63	12·07	..	12·98	11·72	9·79
TOTAL .	100·47	99·31	99·31	100·02	99·96	100·51

1. Near Kumardhubi, Manbhum district. Barakar fireclay used in the Kumardhubi Fireclay and Silica works. Analysis by Bird & Co.
2. Raniganj coalfield, Manbhum district. Barakar fireclay used in the Kumardhubi Fireclay and Silica works. Analysis by Bird & Co.
3. Raniganj coalfield, Manbhum district. Calcined clay from Barakar beds. Used in the Kumardhubi Fireclay and Silica works. Analysis by Bird & Co.
4. Patlabari, Manbhum district. Analysis by Bird & Co.
5. Mahaldih, Jharia coalfield, Manbhum district. Refractoriness cone 31. Free silica 18·64 percent. Analysis by the Bihar Fire-bricks & Potteries, Ltd.
6. Rajhara, Palamau.

On the Raniganj coalfield the carbonaceous fireclays occur near the Damodar and Barakar rivers, over quite a large area. The seams vary from 1 foot 6 inches to 3 feet and more in thickness, the average being about 2 feet. They are interbedded with sandstones and dip at a fairly steep angle. The quality of the clays varies widely, but by mixing material from different sources clays of suitable properties can be obtained.

On the Jharia coalfield the fireclays are found mainly in the vicinity of Jharia station and towards Pathardih station (23° 40′ : 86° 26′) close to the edge of the coalfield. The seams of fireclay, interbedded with sandstones, vary from 18 inches to several feet in thickness, averaging perhaps 2 feet 6 inches. The quality of the clays varies greatly on the Jharia coalfield; there are many clay-seams which are useless for firebrick making, and all require careful selection and blending with clays from other districts for the manufacture of high-grade refractories. Variation in quality down the dip is sometimes noticeable.

On the Daltonganj coalfield fireclays are worked near Rajhara station (24° 00′ : 84° 14′). The seam averages about 10 ft. thick; lime nodules have to be removed. It is a good plastic fireclay and is used for mixing with harder clays from the Raniganj coalfield.

Obviously the reserves of these classes of clays in Bihar are great but will depend upon the economic limit of depth to which they can be mined.

Clays of presumably Archean age from Pirpahar (25° 23′ : 86° 31′), 3 miles east of Monghyr, were also used at one time for refractory purposes. They appear to be equally suitable for pottery ware.

China-clay and kaolin.—Beds of white clay in the Gondwanas are used as china-clays for the manufacture of pottery. Seams of white clay, 4 to 5 feet in thickness, are found in the Rajmahal hills, near Hura (24° 59′ : 87° 23′) and at other places along the western margin of the hills. At Mangal Hat (25° 04′ : 87° 51′) china-clay is obtained by crushing the sandstone and washing out the clay constituent—this is the material used by the Bengal Pottery, Ltd.

Kaolin is formed in rocks as a result of the decomposition of felspar. Although there is a distinct mineral known as kaolinite, clays of this origin consist of a mixture of kaolinite with other similar minerals, and fine colloidal material. Hence their composition and

physical properties vary somewhat. The majority of kaolin deposits have been formed by the alteration of granite, either in consequence of weathering or as a result of hot solutions or gases which have permeated the rock.

Kaolin deposits normally contain much fine quartz which it is necessary to remove by washing. The clay is carried off with the water and allowed to settle. The proportion of clay to rejected material is generally less than 25 percent. In Bihar, the best kaolin is produced in Singhbhum, near Hat Gamaria (22° 16′ : 85° 45′), where the quality was probably at one time equal to the best Cornish clays, and the price realised was Rs. 30 per ton, which, although only half the price of Cornish clays, is far higher than that of other Indian kaolins. The Singhbhum kaolin has been extensively used by Indian textile industries. One of the difficulties of kaolin deposits in Bihar is the wide variation of quality even within the one deposit, so that their products are not regarded as being as reliable as imported clays.

Some analyses of Bihar china-clays are given in Table 8.

TABLE 8.—*Analysis of Bihar china-clays.*

——	1	2	3
	Percent	Percent	Percent
SiO_2	57·00	55·00	48·95
Al_2O_3	39·11	40·38	36·28
$FeO+Fe_2O_3$	trace	trace	0·89
TiO_2	..	..	..
MgO	1·21	1·32	0·65
CaO	1·42	2·20	0·86
Na_2O, K_2O	1·26	1·00	..
H_2O	14·00	10·00	11·48
TOTAL	114·00	110·00	99·11

1. Patharghatta hill, Bhagalpur district. Kaolin. The analysis is of ignited clay. The loss by ignition was recorded separately. The clay was dried at 212°F. Analyst, G. Macdonald, 1860.
2. Patharghatta hill, Bhagalpur district. Fine white clay. The analysis is of ignited clay. The loss by ignition was recorded separately. The clay was dried at 212°F. Analyst, G. Macdonald, 1860.
3. Hat Gamaria, Singhbhum. Kaolin. 4·88 percent of the SiO_2 is insoluble. This is the average of 6 analyses of best quality kaolin.

Lithomarges.—In consequence of certain peculiar changes which take place in rocks during the formation of laterite, a zone of clayey

material of very varied composition is usually formed immediately beneath the lateritic surface layer. This zone is usually ferruginous, but is higher in alumina and lower in silica than is kaolin. Lithomarge may vary in colour from white, where free from ferric oxide, to deep red-brown, according to the amount of ferric oxide present.

According to Bates a characteristic of lithomarge is that it will not remain in suspension no matter how finely ground. It cannot, therefore, be used for some of the purposes for which china-clay is used. An analysis of lithomarge from Serendag (23° 22′ : 84° 28′), Ranchi district, is given in Table 9.

TABLE 9.—*Serendag lithomarge.*

	Percent
SiO_2	46·75
Al_2O_3, $FeO+Fe_2O_3$, TiO_2	39·59
MgO	0·22
CaO, Na_2O, K_2O	0·58
H_2O	12·70
TOTAL	99·84

Localities.

Bhagalpur district.—Kaolin occurs in the weathered gneiss and in the overlying Gondwana sandstones at Patharghatta hill (25° 20′ : 87° 16′) on the Ganges near Colgong, and in the adjacent hill of Kasdeh. These deposits were first worked in 1860. In the gneiss the kaolin is said to extend down to 100 feet, whilst the clay beds in the sandstone total 40 feet in thickness, each bed being 3 to 4 feet thick. High quality pottery was turned out between 1860 to 1864. In more recent years the clay has been worked and despatched to Calcutta (6) by the Bengal Potteries, Ltd.

Good quality clays have also been reported from Samukhi (24° 57′ : 86° 52′) and Letwabaran (24° 39′ : 86° 51′), Banka subdivision.

Gaya district.—A sample of kaolin from a place given as Kowakola in Nawadih subdivision was found to be of fair quality on testing in the Geological Survey laboratory. Details of the field occurrence are not known, but the locality is probably Kauakol (24° 51′ : 85° 53′).

Hazaribagh.—Fireclay has been obtained from Emlo (23° 48′ : 86° 00′), presumably from the Gondwanas.

Manbhum district.—Kaolin is found in granite in many places, but is usually of inferior quality. Ball records (5, p. 112) an occurrence at Katras (23° 48′ : 86° 21′). It has also been worked at Taldih (23° 24′ : 85° 56′) and near Tundi (23° 59′ : 86° 27′). It is associated with schists in the southern part of the district near Rajabasa (22° 49′ : 86° 29′), at Dandudih (22° 59′ : 86° 33′), Tamakhun (22° 59′ : 86° 36′) and Balrampur (22° 59′ : 86° 38′) (9, p. 231). The clay from Balrampur is used as paper filler.

Fireclays are quarried from Barakar rocks at numerous places on the Raniganj coalfield, the principal firms being Kumardhubi Fireclay and Silica Works, Ltd., Reliance Firebricks and Pottery Co., Ltd., Burn & Co., and Bihar Firebricks and Potteries, Ltd. The clay beds are up to 4 feet in thickness. The clay is grey to black before burning, but burns to a white or cream colour. The plasticity is variable, as also are the contraction percentages and refractoriness. Most of the deposits are near Kumardhubi (23° 15′ : 86° 47′). The localities are: Chhatabar (23° 45′ : 86° 44′), Mugma (23° 45′ : 86° 45′), Palasia (23° 44′ : 86° 45′), Marmah (23° 46′ : 86° 47′), Mera (23° 45′ : 86° 48′), Rajpura (23° 46′ : 86° 46′), Birsinghpur (23° 47′ : 86° 44′), Sangamahal (23° 45′ : 86° 44′), Ketharidih (23° 44′ : 86° 28′), Kapasara (23° 46′ : 86° 45′), Chirkunda (23° 44′ : 86° 48′) and Brindabanpur (23° 34′ : 86° 46′).

On the Jharia coalfield, fireclays are worked by the Bihar Firebrick and Potteries, Ltd., from the lower Barakar beds near Tetulmari railway station (23° 49′ : 86° 20′). They occur in discontinuous beds, one to three feet in thickness, parallel to No. 9 coal seam. The Kumardhubi Fireclay and Silica Works, Ltd. obtain clays from Parbad (23° 42′ : 86° 27′) and Makunda (23° 44′ : 86° 28′), and other deposits occur at Sulunga (23° 43′ : 86° 28′) and Chandkuiya (23° 45′ : 86° 28′).

Monghyr district.—A good quality kaolin has been reported from Nawadih (24° 47′ : 86° 23′). At Pirpahar, 3 miles east of Monghyr, a clay deposit was at one time worked by the E. I. Railway for the manufacture of firebricks used in the Jamalpur workshops. The quarry is at present abandoned as the firebricks are now purchased from manufacturers. According to P. K. Chatterjee the deposit is extensive and the clay is hard, fine and of good plasticity; it should be suitable for pottery-ware and as a filler (14, p. 6). Another similar deposit occurs about a mile to the southeast of Pirpahar.

Palamau district.—Fireclays occur at Rajhara (24° 06′ : 84° 8′) on the Daltonganj coalfield and are used by the Reliance Firebrick and Pottery Co.

Ranchi district.—Lithomarge is found in large quantities below the laterite on Serandag plateau (23° 22′ : 84° 28′), Bagru Pat (23° 29′ : 84° 36′), Dischmatia Pat (5 miles west of Lohardaga) and on the other plateaux in western Ranchi district. Some of these are said to have some of the properties of fuller's earth (7, pp. 32, 167-182).

A specimen of clay from near Ranchi, submitted to the Geological Survey laboratory, was found to be suitable for making firebricks. The exact locality is not known.

Singhbhum district.—Kaolin deposits occur at many places in Singhbhum. Most of them occur within the granite; others have been formed by alteration of the rocks close to the granite (8, pp. 163-164; 9, pp. 229-231). Localities recorded are: near Hat Gamaria (22° 16′ : 85° 45′), Kashmandu (22° 10′ : 85° 45′), Katahpara (22° 13′ : 85° 43′), Mahuldiha (22° 14′ : 85° 41′), Telaipi (22° 25′ : 85° 55′), Karanjia (22° 07′ : 85° 45′), Pandrasali (22° 38′ : 85° 48′), Majri (22° 42′ : 85° 40′), Madkumhatu (22° 32′ : 85° 48′), Metiabandi (22° 33′ : 86° 38′), Kharhi dungri (22° 32′ : 86° 46′), and Dharadih (22° 43′ : 86° 32′). Of these deposits, those in the vicinity of Hat Gamaria have produced a better quality kaolin than in most others (10, p. 299). These deposits south of Hat Gamaria extend to a depth of at least 70 feet, but the ratio of material excavated to refined clay is only 18 to 1. Some of the clays in Singhbhum are only used locally as a colour wash.

Santal Parganas.—Kaolin occurs in many parts of the Rajmahal hills, both as an alteration product of the schists and granites, and of the felspar in the Damodar sandstone (6). The best deposits are said to occur at Dudhan (24° 16′ : 87° 24′), Karanpur (24° 20′ : 87° 23′), and Katangi near Baskia (24° 27′ : 87° 23′). Other small deposits are reported near Bagmara (24° 38′ : 87° 17′), Bhurkunda (24° 20′ : 87° 21′) and Rajabhita (24° 56′ : 87° 22′). At Mangal Hat (25° 04′ : 87° 51′) the clay is extracted from the sandstone by crushing and washing, and is used by the Bengal Pottery Ltd.

Fireclays are found as beds interstratified with the Damodar sandstones along the western margin of the Rajmahal hills, near

Piarim (25° 00′ : 87° 24′) and on the southern side of the stream near Hura (24° 59′ : 87° 23′) in the Hura coalfield, and also in the Dhamni and Chuparbhita coalfields (6).

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CHAPTER XVI.

COAL.

General.

India's industrial development has been founded on the country's coal resources. The coal trade is of such dimensions that India has held for many years the position of the largest coal producer amongst the British dependencies. Within India, over 50 percent of the total annual output is from Bihar coalfields. The output figures for Bihar and all India, during recent years, are given in Table 10.

TABLE 10.—*Production of coal.*

Years.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1929 . . .	(a) 15,133,144	5,37,64,328	23,418,734	8,93,59,124
1930 . . .	(a) 15,064,425	5,52,33,360	23,803,048	9,26,25,323
1931 . . .	(a) 13,532,794	4,87,78,145	21,716,435	8,26,98,364
1932 . . .	(a) 11,847,216	3,78,23,891	20,153,387	6,80,96,604
1933 . . .	(a) 11,257,984	3,32,42,520	19,789,163	6,11,86,083
1934 . . .	(a) 12,630,409	3,42,00,225	22,057,447	6,30,60,951
1935 . . .	(a) 12,438,058	3,29,60,609	23,016,695	6,52,20,840
1936 . . .	12,016,914	3,15,13,969	22,610,821	6,24,98,404
1937 . . .	13,836,717	4,09,23,918	25,036,386	7,81,02,439
1938 . . .	15,364,079	5,37,10,370	28,342,906	10,64,23,835
1939 . . .	14,787,661	4,84,02,895	27,768,761	9,87,23,916

(a) Includes Eastern States and Orissa.

Although coal was known to occur in Bihar long before European trade began to open up the country, and a certain amount was obtained for use in Calcutta from the Raniganj field during the latter part of the eighteenth century, it was not until reports

by the Coal Committees of 1838 and 1846 that the coalfields began to be investigated and worked in earnest. Production gradually increased until, during the 1914-1918 war, from Bihar alone an annual output of over 15 million tons was attained. Since then the output from this province has fluctuated slightly between 12 million and 15 million tons, dropping in only occasional years below the former figure. Unfortunately, however, the price of coal began to fall in 1923 and continued to do so until the last three or four years, so that the total annual value of the coal produced has fallen far short of the pre-1923 figures.

Almost the entire output of Indian coal is consumed in the country, exports rarely exceed one million tons, most of this going to Ceylon and Hong Kong. In India, approximately one-third of the coal produced is consumed by the railways, one-quarter by the iron and steel industry (including engineering workshops), 10 percent is used by the collieries (including also wastage), and perhaps 6 percent is used for bunkering ships at the various ports. The remainder is distributed over a large number of consumers, the principal being cotton mills, jute mills, inland steamers, brick kilns, potteries, cement works, tea gardens, and paper mills.

Not only does the coal industry give direct employment to a labour force of between 160,000 and over 200,000 persons, but transport of coal is a great source of revenue to the railways, and coal consumption in all its ramifications through trade and commerce in India is the basis of a vast amount of employment.

In the bibliography at the end of this chapter references to only the more recent literature dealing with the geology and reserves are given, as the accumulated written material on these fields has assumed enormous dimensions. This chapter can, also, only hope to summarise the more salient features of the coalfields. The most recent summarised account of these coalfields was given by Fox in 1934 in *Memoirs of the Geological Survey of India*, volume LIX.

Uses.

Apart from its direct use as fuel for power purposes, an average of approximately two million tons of coal from the Bihar fields

are converted into hard coke for metallurgical purposes. Only a certain comparatively small percentage of Bihar's coal reserves is suitable for manufacturing into hard coke direct, but, by suitable blending, coals which are otherwise unsuitable may be used; there is room for much research on the blending of coals for coking purposes. An increasing quantity of soft coke is being manufactured from inferior grades of coal and used for domestic fuel; the amount of soft coke produced from Bihar coal has now reached approximately one million tons per year. During the manufacture of hard coke several by-products are formed, such as volatile oils, tar, ammonia and napthalene, which are now collected in most plants. Although the use of these by-products for the development of other industries in India has not attained the dimensions of the coal by-product industries in Europe and America, there is little doubt that their use will receive increasing attention in the future.

Grading and composition.

Under an Act of Legislature in 1925 a Coal Grading Board was constituted to arrange for the classification and certification of exported coal. The following are the grades of Indian coals fixed by the Board:

Low volatile coals.—(*a*) Selected grade, up to 13 percent ash and over 7,000 calories (12,600 B. T. U.'s). (*b*) Grade No. 1, up to 15 percent ash and over 6,500 calories (11,700 B. T. U.'s). (*c*) Grade No. 2, up to 18 percent ash and over 6,000 calories (10,800 B. T. U.'s). (*d*) Grade No. 3, all coals inferior to the above.

High volatile coals.—(*a*) Selected grade, up to 11 percent ash; over 6,800 calories (12,240 B. T. U.'s) and under 6 percent moisture. (*b*) Grade No. 1, up to 13 percent ash; over 6,300 calories (11,340 B. T. U.'s) and under 9 percent moisture. (*c*) Grade No. 2, up to 16 percent ash; over 6,000 calories (10,800 B. T. U.'s) and under 10 percent moisture.

There is a considerable range in the character and quality of the coals found in the province, not only between separate coalfields, but also between coals of the various seams on each coalfield. These differences may be appreciated from the analyses of coals from the various parts of the province, given in Table 11.

TABLE 11.—*Analyses of Bihar coals.*

Name of seam.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value.	Remarks.
	Percent.	Percent.	Percent.	Percent.	Calories.	
			RANIGANJ COALFIELD.			
Raniganj Series—						
Ghusick—Upper Kajora Seam.	7·05	33·35	54·50	12·15	6,965	
Nega—Lower Kajora Seam.	6·10	32·10	53·65	14·25	6,844	
Jambad Seam . .	8·30	33·80	54·70	11·50	6,807	
Samla Seam . .	9·80	32·10	55·10	12·50	6,800	
Dishergarh Seam .	2·52	37·75	51·55	10·70	7,273	
Poniati Seam . .	5·10	31·30	57·80	10·90	7,047	
Barakar series—						
Chanch—Begunia seam	2·10	27·00	60·00	12·40	7,194	
Ramnagar seam .	2·0	27·4	55·20	15·40	..	
Laikdih seam . .	1·40	26·0	62·60	11·40	7,632	
Kasta seam . .	2·66	32·05	57·00	10·95	7,318	
Damagaria seam .	1·24	23·00	62·00	15·00	7,149	
			JHARIA COALFIELD.			
Raniganj series—						
North Pipratanr Seam	1·07	32·0	53·3	14·7	..	
Huntodih (top) Seam .	2·07	32·2	52·75	15·05	7,084	
Bhatdih Seam . .	1·7	31·0	54·5	14·5	7,001	
Murilidih Seam . .	2·2	29·3	57·0	13·2	7,096	
Barakar series—						
Jamadoba (XVIII) Seam.	1·70	28·10	56·80	15·10	..	
Noonudih (XVIII) Seam.	1·80	28·8	59·3	11·9	7,209	
Bhutgooria (XVII) Seam.	2·0	28·13	58·85	13·02	7,201	
Bhagaband (XVII) Seam.	1·6	27·2	59·6	13·2	7,269	
Bhagaband (XVI) Seam.	1·3	24·5	60·2	15·3	7,240	
Lodna (XIV) Seam .	1·6	24·6	61·0	14·4	..	
Bhuggutdih (XIV) Seam.	1·27	22·85	64·7	12·45	7,457	
Khas Jharia (XII) Seam.	1·15	21·65	62·35	16·00	..	
Kamradih (XII) Seam	0·75	20·1	65·3	14·6	..	
Dhariajoba (X) Seam .	1·0	19·0	62·4	18·6	6,809	
Dhansar (VIII) Seam .	1·0	17·3	61·57	21·13	..	
Narkhari (V) Seam .	0·65	14·1	66·2	19·7	6,926	
Matiagara (II) Seam .	0·65	14·2	68·0	17·8	7,141	
			BOKARO COALFIELD.			
Barakar series—						
Kargali Seam . .	1·16	23·57	58·96	16·31	7,140	Sulphur 0·465.
			SOUTH KARANPURA COALFIELD.			
Barakar series—						
Argadu Seam . .	4·15	32·85	50·85	16·8	6,646	
Sirka Upper Seam .	1·91	31·19	51·55	15·35	6,525	Sulphur 0·65.
			HUTAR COALFIELD.			
Barakar series—						
Deori nala No. 3 Seam	11·42	31·33	47·37	9·88	5,398	
			DALTONGANJ COALFIELD.			
Barakar series—						
Rajhara Seam . .	9·10	37·40	52·10	10·50	..	
			GIRIDIH COALFIELD.			
Lower Karharbari seam—						
Top of Seam . .	1·40	26·50	64·34	7·40	..	Sulphur 0·38.
Middle of Seam . .	1·20	25·50	65·94	7·00	..	Sulphur 0·36.
Bottom of Seam .	1·60	23·50	69·53	5·00	..	Sulphur 0·37.

Distribution.

The coal production of Bihar is entirely from Gondwana rocks, a summary of the sequence of which has been given in Chapter III. The coal seams are confined to the lower Gondwanas, to the Barakar and Raniganj stages of the Damodar Series which, together with the intervening Barren Measures, total nearly 7,000 feet in thickness. In the Barakar or lowest stage of this series in the Jharia field there are eighteen workable seams totalling nearly 200 feet of coal. In the Raniganj or upper stage of the Raniganj field there are six important seams, but the latter are largely outside the limits of Bihar. The seams are laminated and well-bedded, and some may be as much as 40 feet or even more in thickness. Some seams, when followed laterally, split or unite, others pass gradually into carbonaceous shale. The seams are interbedded with sandstones and shales; as a rule the sandstones overlie the coal and the shales are below. Pebbles are commonly seen in the sandstones immediately above the coal. Generally, the beds are gently inclined or horizontal, except in the vicinity of faults where they may be steeply inclined or even vertical. Most of the coal basins are bounded to a large extent by faults.

A total of twentyone coalfields may be counted in Bihar, five arranged along the western edge of the Rajmahal Hills, nine along the Auranga-Damodar valleys, and seven in a belt to the north and parallel to the latter.

The coalfields are grouped as follows, according to districts, numbers refer to those shown on the mineral map:

Manbhum.—(1) Raniganj (part in Bengal), (2) Jharia, (3) Chandrapura.

Hazaribagh.—(4) Bokaro, (5) Ramgarh, (6) South Karanpura, (7) North Karanpura (part in Palamau), (11) Itkhori, (12) Chope, (13) Giridih.

Palamau.—(8) Auranga, (9) Hutar, (10) Daltonganj.

Santal Parganas.—(14) Jainti, (15) Sahajuri, (16) Kundit Karaia, (17) Brahmani, (18) Pachwara, (19) Chuparbhita, (20) Jilbari, (21) Hura.

The Jharia, Raniganj and Bokaro fields, in that order, are easily the most important, the Giridih and Karanpura fields are also large

producers, whilst from each of the remaining fields there is either a very small output or none at all.

Raniganj coalfield.—Lying between longitudes 86° 36′ and 87° 20′ the present proved limits of this area of Gondwana rocks occupies about 600 square miles, but only the western end, west of the Barakar river, lies in Bihar.

The better quality seams of this field are, with one or two exceptions, confined to the Raniganj coal measures and these are largely outside the limits of Bihar. These measures include the following seams ranging from 10 to over 20 feet in thickness—Ghusick - Upper Kajora, Nega - Lower Kajora, Jambad, Dishergarh, Sanctoria - Poniati. Of these, only the Dishergarh and possibly the Sanctoria seam (so far undeveloped) are of workable thickness in Bihar; they occur in the area lying south of the junction of the Barakar and Damodar rivers and the former is worked in the important collieries of Deoli, Saltor and Parbelia.

In the Barakar coal measures, the important seams include the Kalimati - Damagaria, Shampur - Laikdih and Chanch - Begunia seams though others of inferior quality occur within Bihar to the west of the Barakar river. Including bands of inferior coal and shale, the seam at Kalimati is nearly 50 feet thick, while the Laikdih has been proved to be of even greater thickness to the west of the Barakar river.

The Barakar coals have relatively low moisture, ranging from 1 to 3·30 percent; comparatively low volatile contents, ranging usually from 21 to 30 percent; a high proportion of fixed carbon, ranging from about 52 to 64 percent. The better quality coals are excellent steam coals and tend to yield hard coke. The Raniganj coals have relatively high moisture, ranging from about 3 to 10 percent (though 1·35 to 3 percent is often recorded for the Dishergarh seam); high volatiles, from 29 to 38 percent. Apart from the Dishergarh and Sanctoria seams, the Raniganj coals are either non-coking or produce a soft coke. The better quality coals are usually excellent gas coals and free-burning steam coals.

The reserves of coking, non-coking, and inferior quality coals from the various seams were given by Gee in 1934, and are quoted in Table 12, but no calculation has been made of what proportion of the total occurs in Bihar.

TABLE 12.—*Coal reserves, Raniganj field.*

Name of seam.	ORIGINAL QUANTITY (EXPRESSED IN TONS). To a depth of 1,000 feet.	To a depth of 1,000 feet.
COKING COALS OF SUPERIOR QUALITY.		
Ramnagar	12,066,000	22,227,000
Laikdih	18,343,000	31,298,000
Begunia	12,193,000	26,672,000
Sanctoria	13,336,000	13,336,000
Dishergarh	106,853,000	237,372,000
Original total	162,791,000	330,905,000
Amount already exploited	81,000,000	81,000,000
Present reserves	81,791,000	249,905,000
NON-COKING COAL OF SUPERIOR QUALITY.		
Damagaria-Salanpur 'A'	62,006,000	99,156,000
Gourangdi-Kasta	24,475,000	43,020,000
Shampur '5'-Laikdih-Bahira '3'	43,156,000	113,736,000
Top Fotka-Chanch-Begunia	27,294,000	57,078,000
Sanctoria-Poniati	170,335,000	324,379,000
Dishergarh	29,060,000	152,170,000
Samla	131,582,000	131,582,000
Raghunathbati	8,764,000	8,764,000
Jambad-Bowlah	132,090,000	132,090,000
Nega-Raniganj-Lower Kajora	261,766,000	307,490,000
Ghusick-Siarsol-Upper Kajora	172,225,000	300,374,000
Satpukhuriya	8,891,000	8,891,000
Original total	1,071,644,000	1,678,730,000
Amount already exploited	108,000,000	108,000,000
Present reserves	963,644,000	1,570,730,000
COAL OF INFERIOR QUALITY.		
Original total	4,712,142,000	6,940,291,000
Amount already exploited	81,000,000	81,000,000
Present reserves	4,631,142,000	6,859,291,000
TOTAL RESERVES OF COAL OF ALL KINDS.		
Coking coal of superior quality	162,791,000	330,905,000
Non-coking coal of superior quality	1,071,644,000	1,678,730,000
Coal of inferior quality	4,712,142,000	6,940,291,000
Original total	5,946,577,000	8,949,926,000
Present reserves	5,676,577,000	8,679,926,000

Jharia coalfield.—This field lies between longitudes 86° 06′ and 86° 30′, and covers an area of about 175 square miles. A large part of this is made up of Talchir rocks, however, and only 84 square

miles is covered by the Barakars and 21 square miles by the Raniganj beds. Fox groups the coal seams of the Barakar series into the following stages:

4. Phularitanr stage, comprising seams XVIII, XVII, XVI.
3. Barari stage, comprising seams XV, XIV-A, XIV, XIII.
2. Nardkarki stage, comprising seams XII, XI, X, IX, VIII.
1. Golakadih stage, comprising seams, VII, VI, V, IV, III to base.

The reserves of the Phularitanr and Barari stages are of coking coals. The other stages yield non-coking coals. The Barakar series contains at least 24 seams of over 4-foot thickness, twelve being workable and aggregating 75 feet, whilst six seams are of considerable thickness and value. Seams Nos. XIV, XIV-A, XV, XVII, and XVIII are amongst the best steam and coking coals available in India. The Raniganj seams in the Jharia field are of less importance than the Barakar, being fewer in number and thinner.

Fox has calculated the reserves of coals from the various stages in the Jharia field, and these are quoted in Table 13.

TABLE 13.—*Coal reserves in the Jharia field.*

Seam.	Millions of tons at depths of		
	500 feet.	1,000 feet.	2,000 feet.
Telmucha stage	17	29	29
Muruhdih	36	61	61
Phularitanr	115	225	225
Barari	293	568	731
Nardkarki	580	1,100	1,550
Golakadih	630	1,103	1,575
Extras	36	36	36
TOTAL	1,707	3,122	4,237

Chandrapura coalfield.—At the extreme western end of the Jharia coalfield, and separated from the latter by a strip of Talchirs, there is a small area, about 400 acres, of Barakar rocks, south and south-east of Chandrapura railway station (23° 45′ : 86° 07′). It contains 9 seams, and Fox calculates that the reserves of coal amount to about 15 million tons, most of which is of inferior quality.

Bokaro coalfield.—The eastern edge of this field is only two miles west of the Talchirs extending west from the Chandrapura coalfield. It forms a long narrow strip of Gondwanas mainly along the valley of the Bokaro river, between longitudes 85° 25′ and 86° 05′. The field may be divided into two parts: East Bokaro, east of longitude 85° 42′, and West Bokaro to the west. To date, mining has been concentrated on East Bokaro, and almost entirely restricted to the Kargali seam. Other seams occur in East Bokaro, the more important in downward succession being:—

12-foot A seam.
Kargali (100-foot) seam.
Bermo (40-foot) seam.
Karo (80-foot) seam.

There are nineteen seams over 4 feet in thickness. Fox estimates that 1,000 million tons of coal are available of which half is of good coking quality.

The West Bokaro field has not been surveyed in great detail, but the seams appear to be more disturbed and less attractive than to the east. However, not sufficient work has been done as yet for definite conclusions to be drawn as to the reserves of better quality coals available.

Ramgarh coalfield.—This field, about 5 miles south of the Bokaro coalfield, extends along the valley of the Damodar river between longitudes 85° 31′ and 85° 42′, covering an area of about 40 square miles. Three seams have been proved, 36 feet, 26 feet and 30 feet in thickness respectively, and of these only the middle 6 feet of the 26-foot seam is workable. The field has not been surveyed in detail, however, all that can be said is that a minimum of 5 million tons of workable coal is available over an area of at least one square mile.

South Karanpura.—This field covers an area of 75 square miles between longitudes 85° 09′ and 85° 30′. Production commenced from this and the larger North Karanpura field in 1925 and development has increased considerably since the Barkakana-Daltonganj railway was opened. The number and thickness of the seams developed in the Barakars of this field are comparable with the best areas of the Jharia coalfield. Some of the seams are of unusual thickness; one of them, the Argada seam, is up to 90 feet. The coal is a low volatile type, is classed as first grade, and much of it is useful for coking purposes. Reserves are at least 750 million tons. Most of the coal is being mined from large open quarries.

North Karanpura.—This field occupies an area of about 550 square miles between longitudes 84° 49′ and 85° 27′. Besides Talchir, Barakar and Raniganj beds, representatives of the Panchets and Mahadevas also occur in this area. Coal seams are found in both the Barakar and Raniganj beds. The field has not been proved in detail, but a large number of seams are known to occur, some over 72 feet thick, some of first class quality and many of second class. Hughes estimated that 8,750 million tons of coal were available. According to Jowett, the total quantity of first and second class coal on the Karanpura fields must amount to between 5,000 and 10,000 million tons down to 2,000 feet from the surface.

Auranga coalfield.—This field, covering an area of over 100 square miles, is situated between longitudes 84° 17′ and 84° 43′, and is traversed by the Auranga river. Several coal seams occur, some of them up to 40 feet in thickness, but they are so high in ash and moisture that they are practically worthless. The seams are also very disturbed by faulting, and dips are commonly steep.

Hutar coalfield.—Covering an area of about 80 square miles between longitudes 83° 53′ and 84° 10′, this field is bisected by the north-flowing North Koel river. The coal seams occur in Barakar rocks, but there are also representatives of the Talchirs and Mahadevas. Five seams are known, these are thin over much of the area, but in places they thicken, one seam of 13 feet 8 inches being known. One 8-foot seam is of first class coal but most analyses show the seams to be of inferior grade coal. According to Dunn, over an area of four square miles 32 million tons of coal are contained in two workable seams.

Daltonganj coalfield.—This field lies to the north of the Hutar coalfield and is outside of the Damodar—Auranga belt. It covers an area of over 200 square miles just to the north of Daltonganj (24° 02′ : 84° 04′), but most of this is occupied by Talchirs, and only about 32 square miles by Barakar coal measures. Several thin seams occur, and, with the exception of a 29-foot seam at Rajhara (24° 10′ : 84° 03′) the seams rarely exceed more than 5 feet. The coal is non-coking and is nearly all of inferior quality. La Touche calculated reserves of 9 million tons in an area of one square mile near Rajhara. The field has been worked in a small way for many years.

Chope coalfield.—Cropping out in the Mohani river a mile and a quarter south of Chope (24° 02′ : 85° 14′), in Hazaribagh district,

there is a small area of Talchir and Barakar rocks covering less than one square mile. A seam, 4 feet thick, of inferior quality coal has been found.

Itkhori coalfield.—A narrow strip of Talchirs with a small area of Barakars extends for 3½ miles west of Itkuri (24° 18′ : 84° 10′) in Hazaribagh. Hughes recognised three seams, one 8 feet thick, but the middle 4-foot seam was the best in quality. He estimated the quantity of coal in the field at 1½ million tons.

Giridih coalfield.—This area of Gondwana rocks covers 11 square miles to the southwest of Giridih (24° 12′ : 86° 18′), Hazaribagh district. There are three main seams, the Lower Karharbari, the Upper Karharbari, and the Bhaddoah seams. The Lower Karharbari seam varies between 10 feet and 24 feet in thickness, and provides one of the finest coking coals in India for metallurgical purposes. The Upper Karharbari seam varied from 4 to 10 feet in thickness but is now practically exhausted. The Bhaddoah seam averages 6 feet in thickness. Other seams aggregate a thickness of 66 feet, but are of poorer quality. In 1934 Fox estimated the total available coal on the field to be about 49 million tons, but allowing for all losses he would not place life of the field at more than 25 years, even this is almost certainly an over-estimate.

Jainti coalfield.—This field covers an area of about 5 square miles about 6 miles south of Madhupur railway station in the Santal Parganas. Mining is confined to two out of the four seams present, the maximum thickness of which is 7 feet. According to P. K. Chatterjee, 2 million tons of good quality coal are available, of which 1 million tons is coking coal.

Sahajuri coalfield.—This small outlier of Gondwana rocks, totalling 12 square miles, occurs at Sahajuri (24° 08′ : 86° 51′) in the Santal Parganas. The coal present is inferior as it is high in ash. According to P. K. Chatterjee 22 million tons of workable reserves are contained in two seams of 18-25 feet thickness.

Kundit Karaia coalfield.—A small outlier of Gondwanas near Khairbani (24° 04′ : 86° 59′) in the Santal Parganas contains two thin seams of very inferior coal.

Brahmani coalfield.—Lower Gondwana rocks occur in the Rajmahal hills in the valley of the Brahmani river, and contain coal

in the vicinity of Sarsabad (24° 18′ : 87° 32′). According to Chakravarti about 29½ million tons of inferior quality coal are present in a seam which is up to 4 feet in thickness.

Pachwara coalfield.—Coal is worked in a small way in lower Gondwana rocks near Bargo (24° 30′ : 87° 24′) and Chilgo (24° 33′ : 87° 28′) in the Rajmahal hills, Santal Parganas. They are all inferior high moisture coals.

Chuparbhita coalfield.—Lower Gondwana rocks between Dhammi (24° 48′ : 87° 29′) and Jiajori (24° 45′ : 87° 26′) contain several seams up to 9 feet in thickness, but all of poor quality.

Jilbari coalfield.—Coal has been worked in Lower Gondwana rocks at Jilbari (24° 51′ : 87° 24′), where two seams of poor quality coal are available; one is 6 feet in thickness.

Hura coalfield.—Near the northern end of the Rajmahal hills, between Daria Chak (25° 08′ : 87° 22′) and Kisma (24° 56′ : 87° 25′), there is an area of Damodar series rocks from which Ball recorded a nine-foot seam of poor quality coal near Chhota Bhorai (25° 02′ : 87° 23′).

Reserves.

In the following estimates it should, of course, be remembered that the greater part of the Raniganj field lies in Bengal.

In 1934, Fox calculated the total amount of coal in these fields to be as follows:

	Million tons.
Giridih and Santal Parganas	250
Raniganj, Jharia, Bokaro and Karanpura fields	25,650
Palamau district fields	+40
	25,950

Restricting the totals to include only seams over four feet in thickness and averaging 20 percent ash, lying within 1,000 feet of the surface, he estimated:

	Million tons.
Giridih and Santal Parganas	80
Raniganj, Jharia, Bokaro and Karanpura fields	10,150
Palamau	40
	10,270

Estimating for seams of good quality coal of upwards of 4 feet, and to a depth of 2,000 feet, with an ash percentage of 16 (moisture-free basis), the following totals are obtained :

	Million tons.
Giridih and Jainti	40
Raniganj	1,800
Jharia	1,250
Bokaro	800
Karanpura	750
Hutar	32
	4,672

Reserves of coals which yield a hard metallurgical coke are as follows :—

	Million tons.
Giridih	30
Raniganj	250
Jharia	900
Bokaro	320
Karanpura	not estimated.
	1,500

No allowance has been made throughout these estimates for losses in mining. These losses may be very considerable, and the life of some coalfields depends on only one or two seams and not on total reserves. Hence, only a fraction of the total reserves of coal may be available; it is doubtful whether even 30 percent can be counted upon.

If good quality coking coals are considered, and assuming a consumption of 4 million tons per year, Fox estimates the life of the reserves at 400 years, which is reduced to 200 years for an extraction of 50 per cent. But these coking coals are now being used for other purposes besides the manufacture of metallurgical coke, and if this unwise practice is continued, Fox, in 1934, suggested that supplies would be exhausted after about 40 years. This remark applies particularly to the Jharia field.

Future.

It may be expected that the principal development during the next few years will be the gradual extension of production from the Bokaro and Karanpura fields, whilst the Jharia field should,

at least, maintain its past production if greater care is exercised than has been often apparent in earlier years. The Giridih coalfield may be expected to maintain production for a few years yet before exhaustion of the seams leads to gradual closing down of the collieries.

So far as production and development is concerned the coal companies are fully able to look after their interests and to increase production up to the market's capacity for absorption. It is, perhaps. too much to hope that the smaller companies would voluntarily amalgamate in some way, even if only to market their coal in the most rational manner, but some form of co-operation is essential for maximum conservation of the country's coal resources. There is yet another point of view which experience of the past has demonstrated is important to the conservation of the country's coal reserves, and it is that each coalfield should be developed on a plan which will ultimately lead to the minimum of wastage. Independent and indiscriminate mining on the part of individual coal companies, with little central control by Government, apart from that permitted by the Mines Act, has been the cause of great losses in reserves on the Jharia and Raniganj fields. These losses should be avoided in the more western fields now being opened up. It can only be done by working according to a definite plan of development, comprising both a coordinated sequence of seams and of areas to be worked, mining good and poor qualities, coking and non-coking, impartially. Perhaps it is not too late to do this in parts of the Jharia field even now. To construct such a plan would require a very full knowledge of the structure and seams of each field. In new fields this can only be obtained by extensive boring, and it is unlikely that Government can assume the expense of this. There is, of course, the alternative of Government recovering such expense by means of a cess from any lease taken on a coalfield explored in this way. However, it seems to the author that some form of Government control of the actual sequence of working the individual seams in these coalfields, and of the purpose for which the coal of various seams is to be used, is the only way to avoid a repetition of the past losses and waste which have been so characteristic of the Raniganj, Jharia and Giridih fields.

The reservation of high quality coking coals for metallurgical purposes has, of course, become a necessity, though in the case of those fields already developed this principle obviously has its

limitations on economic grounds. In future planning, in fields now being opened, coal suitable for metallurgical purposes should be reserved for those purposes and used for no others. It should always be remembered that these are resources on which India's industry is to depend in future, they have an infinitely greater meaning than the profits of individual zamindars or coal companies, and their future misuse will mean that India's industry—and the country itself—will be the ultimate sufferer. It is essential that everyone connected with the coal trade should take a long view in this matter.

Regarding the future utilisation of Indian coals, the possibility of cleaning many of the high ash coking coals is undoubtedly of prime importance to Bihar. Other lines along which investigation is required include improvements in the domestic fuel industry together with the recovery of the more valuable by-products, and in the efficient consumption of coal in the pulverised state.

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CHAPTER XVII.

COPPER.

General.

Many centuries ago, copper was smelted in considerable quantities in Chota Nagpur, but this ancient smelting industry had long died out and it is only in recent years, in Singhbhum district, that copper smelting has been revived by modern methods.

In southern Chota Nagpur a copper-bearing belt, some 80 miles in length and marked out by old workings, commences at Duarparam on the Bamini river in the Kera Estate, Singhbhum, and strikes in an easterly direction through Kharsawan and Saraikela States into Dhalbhum subdivision, where it curves to the south-east through Rakha Mines and Mushabani (Mosaboni), ending to the southeast at Baharagora. A full account of the history and geology of these deposits has been published in a recent memoir of the Geological Survey by the present writer (10).

The copper-ores of Singhbhum have been the subject of exploitation on European lines by various companies during the past seventy years, always until recently with unsuccessful results due, in some cases, to the poor character of the deposits prospected and in others to the unwise expenditure of limited capital on expensive plant before the deposits were proved. Such results caused business and mining men to avoid investment in the Singhbhum belt, and consequently, during the years 1906-1908, the Geological Survey of India carried out a series of diamond drilling operations along the belt. This work redirected the attention of the public to the area, and the Cape Copper Company, under the management of Messrs. John Taylor and Sons, after a further prospecting campaign, took over the rights of an earlier company, the Rajdoha Mining Company, at Matigara. This property, known as Rakha Mines, was actively developed, and at the end of August, 1918, the company's ore-reserves amounted to 407,000 short tons of an average assay value of 3·8 percent copper. Owing to the difficulty of procuring plant during the war, smelting furnaces were not in operation until 1918. A power house, concentration plant, sintering plant, and furnaces were erected, and a refinery completed during 1919-20. The total production of copper-ore and metal from the Rakha

Mines during the 1919-1923 period amounted to 130,797 and 3,549·76 tons respectively, valued at Rs. 18,08,141 and Rs. 41,58,154. In March, 1923, mining operations were stopped and the company's property was placed in the hands of receivers.

In 1920, the Cordoba Copper Company, also under the management of Messrs. John Taylor and Sons, prospected the Mosaboni area, on an option from the Cape Copper Company, and met with promising results. Two lodes, known respectively as the Main and Western Lodes, were opened up on sulphide ore down to a depth of 500 feet. In 1924, exercising the option, the mining rights were purchased from the Cape Copper Company.

In 1922 another company, the North Anantapur Gold Mines, Limited, also managed by Messrs. John Taylor and Sons, commenced an investigation of the Sideshar-Kendadih area, between the concessions of the Cape Copper Company and the Cordoba Copper Company. About the same time the Ooregum Gold Mining Company prospected a copper lode at Galudih in Kharsawan State, but with little success.

In 1924, the Cordoba Copper Company was reconstructed as the Indian Copper Corporation, Ltd., with a capital of £225,000, and acquired also the neighbouring properties of the North Anantapur Gold Mines, Ltd., and the Ooregum Gold Mining Company. Work was concentrated upon the Mosaboni area, and by the end of April, 1925, nearly 329,000 tons of 4·04 percent ore had been developed. Operations were suspended during 1926 pending the raising of capital required for the erection of the necessary smelting, refining, and power plants. Early in 1927 the Anglo-Oriental and General Investment Trust, Ltd., London, assumed control, a sum of £350,000 was subscribed as debentures for the purpose, and the erection of power plant, concentration mill and smelter was commenced at Maubhandar, alongside the Bengal Nagpur Railway, 6 miles from the mine, near Ghatsila.

In July, 1930, a rolling mill for the production of yellow metal or brass sheet (62 percent of copper and 38 percent of zinc) was completed and the first yellow metal sheet made in India was produced. In 1931 the technical management of the corporation was handed over to the New Consolidated Goldfields, South Africa, Ltd., under whose management operations still continue. In 1932 further debentures for £125,000 supplied funds to increase the plant in order to permit an expanded production of 50 percent. This

extension was completed in October, 1933, and the authorised capital of the corporation now stands at £900,000. With the completion of this extension of plant the production capacity of the corporation is over 6,500 tons of refined copper and 8,000 tons of yellow metal sheet per annum.

The production of copper by the Indian Copper Corporation since smelting commenced is given in Table 14.

TABLE NO. 14.—*Production of copper and brass at Maubhandar.*

Year.	Refined copper ingots	Yellow metal sheet.
	Tons.	Tons.
1929	1,635	..
1930	2,974	718
1931	4,069	3,637
1932	4,443	5,440
1933	4,800	6,143
1934	6,300	8,180
1935	6,900	9,843
1936	7,200	9,877
1937	6,830	8,696
1938	5,330	8,236

Singhbhum ore-deposits.

The copper-ores of Singhbhum are related to tongues of granite which intrude the schists. The ores occur as veins in the granite and in the neighbouring mica-schists, quartz-schists, and epidiorites or hornblende-schists. These veins are best developed along a zone of overthrust, where they form well-defined lodes, as at Rakha Mines (22° 38′ : 86° 22′), Mosaboni (22° 31′ : 86° 28′) and Dhobani (22° 31′ : 86° 27′). At Mosaboni the country rock is granite, altered to chlorite-biotite-quartz-schist along the lode-channels; at Dhobani it is epidiorite altered to biotite-chlorite-schist along the lodes, and at Rakha Mines it is quartz-schist altered to chlorite-sericite-quartz-schist along the lodes. Individual lodes usually consist of one or more veins of "solid" sulphide varying in thickness from one inch to occasionally 2 feet, but the average would be only 5-7 inches. On either side of this the sheared country rock is partially replaced by sulphides up to a variable width. The main sulphides are chalcopyrite and pyrrhotite with also some pyrite, pentlandite, violarite [$(NiFe)_3 S_4$], and millerite. In addition, the gangue includes quartz, chlorite, biotite, tourmaline, magnetite and apatite. At the surface the sulphides have been oxidised, and in the dumps left

by the ancient miners along the old workings specimens of malachite. azurite. chrysocolla, cuprite and native copper are found. Specimens of chalcocite are also seen occasionally. Usually the ancients have mined these ores at the surface so thoroughly that outcrops of vein material are rare.

At the western end of the belt, in North Singhbhum, ancient copper workings are seen at Duarparam (24° 46′ : 85° 34′), Jaypur (22° 45′ : 85° 36′) and Roladih (22° 45′ : 85° 40′), but the veins here appear to be too insignificant to warrant prospecting. In Kharsawan State veins of copper have been prospected at various times without success, particularly at Galudih (22° 47′ : 85° 44′), as also in Saraikela State. Continuing further east into East Singhbhum or Dhalbhum, small copper lodes were prospected as long ago as 1857, between Dhadkidih (22° 44′ : 86° 10′), Nandup (22° 44′ : 86° 12′), Ramchandra Buru (22° 43′ : 86° 13′), and Hitku (22° 43′ : 86° 15′) but without success, and the evidence is not favourable to future prospecting. All of the above veins occur either in granite-schist or in the schists adjacent to the granite.

The most favourable section of the copper belt extends south-east from Rajdah (22° 41′ : 86° 17′) to Badia (22° 29′ : 86° 28′). At Rajdah a lode in mica-schists was worked in 1862 by the Hindustan Copper Company, and some ore was actually smelted and sent to Calcutta, but heavy preliminary expenses ruined the venture. Further work was done in 1891 by the Rajdoha Mining Company, but unsuccessfully. No further prospecting has been carried out here, apart from some diamond drilling by the Cape Copper Company subsequent to 1910. Although the earlier prospecting was admittedly of an unsatisfactory and inconclusive nature, the poor results of the Cape Copper Company's boreholes give no encouragement for further prospecting.

At Rakha Mines (22° 38′ : 86° 22′) the copper lodes are in quartz-schist. The main lode was developed down to a depth of 900 feet, at the 9th level, when mining was stopped in 1922. The average strike length of the workings was about 1,600 ft., the dip of the vein 43°. The lode was almost completely stoped out down to the 6th level. Any further reopening of the Rakha lode will depend entirely on development in depth below No. 6 level. There is another lode in the hanging wall, but it has scarcely been touched and little is known about it. A little to the south are other veins, one of which has been developed from No. 4 shaft down to about

300 feet. On the western side of Rakha ridge there is a line of old workings which were once cleaned out, but no extensive prospecting has ever been done on them.

On the northeastern side of Sideshar, just to the south of Rakha Mines, some prospecting has been done, and further work in this section appears to be desirable. Near Chapri (22° 37′ : 86° 24′), Messrs. Tata Sons, Ltd. and Messrs Gillanders Arbuthnot and Co. in partnership, put down boreholes between 1918 and 1920, but only one gave encouraging results. Presumably the veins here are locally rich but impersistent. A mine was started here by the North Anantapur Gold Mining Co. in 1920 and continued to 1924; the lower of two parallel lodes was prospected, but no copper of commercial value was disclosed. The same company prospected a lode in quartz-schists and chloritic schists near Kendadih (22° 35′ : 86° 25′), but although local patches of good ore were found the results were not encouraging for future work.

A little to the south, at Surda (22° 33′ : 86° 26′), copper veins in a ridge were prospected in 1921 by the Cordoba Copper Company. Good assays were obtained, but the results were inconclusive. There are innumerable veins in the mica-schists and quartz-schists here, but they all appear to be thin. Recently, the Indian Copper Corporation opened up workings here, but operations were suspended in 1938 when about 4,000 tons of an average value of 3·06 percent copper had been developed.

Boring has been carried out at Laukesra (22° 33′ : 86° 27′) and although there is a wide lode the assay results of the borehole samples are not promising and the author would hesitate to encourage prospecting here.

From Laukesra southwards there is an outcrop of granite, and towards the western edge of this occurs a line of copper lodes extending from west of Laukesra, through Mosaboni (22° 31′ : 86° 28′) to south of Badia (22° 29′ : 86° 28′). The northern end of these workings, north of Mosaboni, has been tested recently without promising results.

Two roughly parallel lodes have been worked in the Mosaboni mine, the Main and West lodes. They dip east at approximately 30°-35° from the horizontal and have been developed north and south for a total distance of some 6,000 feet. At the close of 1940 the ore-reserves standing at the Mosaboni mine amounted to about one million short tons with an average assay value of about 2·00

percent copper. Further to the south of Mosaboni, exploration along the same line of workings has been commenced at North Badia and Badia, and ore-reserves amounting to 4,716 tons of an average value of 2·89 percent copper at North Badia, and 59,766 tons of an average value of 2·76 percent copper at Badia, have been opened up. Underground, levels have been driven along the West lode channel, thus connecting Mosaboni mine with North Badia and Badia over a total length of some 15.000 feet, but much of this is barren or unpayable. In addition, a continuation of the Main lode has been exposed at North Badia. but there are so far no indications of the existence of this lode at Badia, where operations have been solely confined to the working of the West lode. At Dhobani, to the west, a parallel lode in epidiorite has been developed, and the ore-reserves standing at the end of 1938 amounted to 127,131 short tons averaging 3·14 percent copper.

South from Badia, indications of only small veins are found south of Gohala (22° 29′ : 86° 30′). near Kanas (22° 30′ : 86° 31′), and at Khejurdari (22° 24′ : 86° 34′), but no indications of veins of any size are observed until the Subarnarekha river is crossed northwest of Baharagora (22° 16′ : 86° 43′). In the granite here. at Thakurdih (22° 18′ : 86° 41′), Jharia (22° 18′ : 86° 42′), Charakmara (22° 17′ : 86° 41′), and Mundadevata (22° 18′ : 86° 42′), there are several long lines of old copper workings which deserve prospecting but have never been investigated in modern times.

Elsewhere, in Singhbhum, small old workings have been seen at Churia Pahar (22° 18′ : 86° 36′) and near Astakoali (22° 21′ : 86° 29′), but these are not worth prospecting.

Other occurrences.

Several attempts have been made within the last 70 years to develop the old Baragunda copper workings (24° 05′ : 86° 04′) in the Giridih subdivision of Hazaribagh district, first brought to notice by Mc Clelland (1) and Smith (4). According to Mallet (6) the ore is of copper pyrites which occurs in lenticular stringers, usually up to ¼-inch thick but sometimes up to 3 or 4 inches, and parallel with the foliation of the schists. An average sample, selected from 250 tons of richer ore, yielded 3·04 percent copper. The country rock is garnetiferous mica-schists with some quartzite, talc-schist and hornblende-schists. The deposit was later described

by Oates in 1895 (9). He found that the ore was in mica-schist, distributed over a zone 7-22 feet in width and averaging 14 feet, the average assay being 1-1·5 percent copper. The ancients mined to a depth of 120 feet along two sections, 1,400 and 1,000 feet in length respectively, the excavations being up to 120 feet in width at the surface. Oates records that the Bengal Baragunda Copper Co., formed in 1882, opened up 5 shafts; the most westerly shaft reached a depth of 330 feet, and from this 5 levels communicated with two other shafts to the east. Over a period of 10 years the maximum monthly production was 40 tons of copper, but the average of the best years was only 25 tons of copper. Water occasioned pumping difficulties. In 1888 the company produced 218 tons of refined copper (8).

In the same district, in the Patru stream near Golgo (24° 24′: 86° 22′), minute particles of chalcopyrite and galena have been noted in a rock consisting of garnet and diopside (7).

Copper minerals have been recorded from two localities in the Santal Parganas. At Bhairukhi (24° 36′: 86° 36′) Sherwill (2) in 1855 excavated narrow veins of copper-ore which strike east and west for 100 feet in tremolitic schist enclosed in biotite-gneiss, often garnetiferous. The veins were followed to a depth of 150, feet by the Deoghar Mining Co. but only a few tons of ore, mixed chalcopyrite and bornite, were extracted as the deposit is poor. A little galena, tetrahedrite, cuprite and copper carbonates are also present. Sherwill also mentioned an occurrence of copper pyrites in the bed of the Ajai river, near Budhbandh (24° 00′: 86° 51′), but it is merely of mineral interest (3).

At Punda (22° 59′: 86° 40′) and Kalyanpur (23° 02′: 86° 02′), in Manbhum, Ball found ancient copper excavations, in which the only signs of copper were the incrustations of carbonates on the schist and quartz debris around the workings (5). Copper mineralisation in Manbhum has been recorded (10, p. 121) also from Kantagora (22° 58′: 86° 42′) and Tamakhun (22° 59′: 86° 36′), but none is of likely economic importance.

The presence of scattered grains of chalcopyrite is commonly noticed in many of the rocks in Chota Nagpur, but they are only of mineralogical interest.

In conclusion it would appear that, apart from the Singhbhum copper belt and possibly the Baragunda deposit in Hazaribagh, the prospects of opening up further copper deposits in Bihar are nil.

Ore-treatment by the Indian Copper Corporation.

The treatment of the ore at this very efficient works is, briefly, as follows :—

The run-of-mine ore is crushed to 4-inch cubes, then hand-picked on belts to remove waste rock when it passes to a secondary crusher, where it is reduced to $\frac{3}{8}$-inch, and is then taken on a belt conveyor to the ropeway storage bins. From the bins the ore is fed to buckets and conveyed a distance of about 6 miles over a mono-cable aerial ropeway to the concentration mill storage bins at Maubhandar. In the concentration mill, after fine grinding in ball mills, the ore goes to froth flotation machines where over 98 percent of the copper is recovered in a concentrate carrying approximately 24 percent copper. After filtering and drying, about one-third of the concentrate passes to a roaster for the removal of sulphur, then this, with the two-thirds sulphide concentrate, is charged into a reverberatory smelting furnace which produces a matte carrying 50 percent copper, and a waste slag. The matte is treated in converters where the sulphur and iron is removed, leaving a low-grade or "blister" copper, which then passes to a refining furnace for the production of refined copper in ingot form. Practically the whole of the refined copper produced by the company is remelted and converted into brass or "yellow metal" by the addition of zinc. The cast yellow metal is rolled in the company's mill into sheet which is wholly marketed in India. All plant at the mine and works is electrically operated by current generated in the company's power plant at the works. The electrical energy is generated by means of pulverised coal-fired water tube boilers and geared high-speed turbo-alternators of a total capacity of 3875 K.W.

Future.

The Singhbhum copper belt has by no means been fully prospected. The Indian Copper Corporation has done sound work in the Badia-Mosaboni-Dhobani-Surda area. There is still scope for smaller companies to prospect other parts of the belt, particularly at the southeast end. There is, however, little room for another smelting company; the present plant of the Indian Copper Corporation should be capable of dealing with all that it would be advisable to produce in this area. Any production outside of the latter's

lease should preferably be sold to the corporation for smelting. Careful examination of milling and transport costs at any particular prospect would decide whether the ore should be concentrated on the spot before despatch to the smelter, or whether the ore as mined should be sent. It is possible that small deposits or pockets of richer ore, capable of being hand-picked, may repay mining and despatch to Maubhandar by individual prospectors or groups of prospectors.

In 1936, attempts at geophysical prospecting were made near Mosaboni and Dhobani. An electrical induction method was used, but the results were entirely unsucessful. In the present stage of our knowledge of geophysical prospecting the author would not recommend the use of such methods over this are in the immediate future.

Copper mining in Singhbhum will always be an anxious undertaking. Assay values and lode dimensions are small and the margin of profits is a minimum, but providing the price of copper remains above £35 per ton, and there are no future serious labour difficulties, the industry should have many years ahead of it. The industry is important both to the province and to India, and every effort should be made to keep up supplies of ore to the smelter.

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CHAPTER XVIII.

GLASS-MAKING MATERIALS.

General.

Since 1914 there has been a gradual development in the glass-making industry in India. However, even to-day imports of glass and glassware into this country are great, the annual value at a minimum being more than one and a quarter crores of rupees and occasionally exceeding two and a quarter crores. There is obviously scope for a very considerable local expansion of this industry.

The development of a glass industry on modern lines in Bihar has, to date, been disappointing perhaps, as only one factory in Patna has come into existence. Yet this province is as well situated for the supply of raw materials as any, indeed, more favourably so than perhaps any other province in India. Also, heavily industrialised as it is, an important market for glassware exists in the province itself. It can only be concluded that the very considerable skill required in the manufacture of glass and glassware has been the obstacle preventing its previous expansion, coupled presumably with the doubt whether manufacturing could be carried on in competition with imported articles.

Raw materials.

The principal constituents used in the manufacture of glass are silica (usually quartz in one of its various modes of occurrence), and soda (usually in the form of sodium carbonate known as soda ash, or sodium sulphate known as salt cake). The fusion of a mixture of these materials in the correct proportions yields a rather soft and easily fusible glass, which is clear if the materials were free from such metallic oxides as iron oxide. A harder glass is made by adding calcium in the form of lime or limestone. If borax is added a clear optical glass results. To correct the greenish tint which may arise from the presence of iron oxide, manganese dioxide is used. Other decolorisers used include nickel oxide and selenium which are not available from India, but are imported. Colouring agents may be added where special coloured glasses are required, such as manganese, chromates, cobalt, nickel and selenium of which all but the first two have to be imported.

In addition to the raw materials for the actual glass itself a reasonably cheap fuel is required. for which purpose the Indian coals are quite suitable. Refractory materials for the construction of the furnaces are also required, but these are readily available in Bihar.

Silica.

As silica is easily the main constituent in the glass batch it is obvious that the sand used must contain an absolute minimum of such impurities as are harmful to the resulting glass. Of these impurities the most serious is iron oxide and the amount of this present should not exceed 0·02 percent if a colourless glass is required; above this a decolorizer must be used, and above 1 percent the glass has a dark green colour. The presence of alkalies in the sand is not deleterious, as alkalies have to be added to the batch in any case. Also, within reasonable limits, the presence of alumina is permissible, particularly for those glasses in which a low coefficient of expansion, increased hardness, brilliancy and strength are required, but it tends to increase the viscosity of the glass melt, requiring a higher fusion temperature. Magnesia also increases the viscosity. Green bottle glass can be made from inferior sands rather high in iron.

The sand grains should preferably average 0·4 mm. in diameter, and in any particular sand used there should not be extreme variations of very coarse material with very fine. However, the tendency has been to exaggerate the importance of grain size; sieving can reduce the extremes to a minimum. A coarse sand will naturally increase the period of fusion of the batch.

The determining requisite of a sand for glass-making purposes is, then, purity. Sands of the necessary composition are rare not only in Bihar, but also in India.

River sands could be used where they are fine-grained and of sufficient purity, but even the best of them would be relatively high in iron and capable of producing only cheap glasses, such as green bottle glass. Along most of the Chota Nagpur rivers, *e.g.* the Son, Subarnarekha, Koel, Auranga, Damodar and Barakar, the sands would be too coarse and would require crushing, but occasionally in some of the wider stretches fine-grained and relatively pure sands are found. No deposit of this nature could be counted upon as a permanent source of supply from year to year.

Analyses of some of these river sands were given by Wagle in 1906 (1), Table 15.

TABLE 15.—*Analyses of some Bihar river sands.*

—	1	2	3	4
	Percent.	Percent.	Percent.	Percent.
SiO_2	83·31	85·19	80·57	82·07
Al_2O_3	7·45	8·30	10·25	9·26
Fe_2O_3	1·95	1·82	2·04	1·61
Mn	0·20	0·15	0·42	0·50
CaO	2·95	1·22	1·57	1·25
MgO	1·02	0·37	0·66	0·31
Alkalies (by difference)	2·37	2·21	4·71	4·15
H_2O	0·75	0·75	0·22	0·55
TOTAL	100·00	100·00	100·00	100·00

1. Ganges sand at Rajmahal.
2. Ganges sand at Colgong.
3. Sand at the junction of the Barakar and Damodar rivers.
4. Barakar river sand at Giridih.

In the Rajmahal hills near Mangal Hat (25° 04′ : 87° 51′), and at Patarghatta Hill (25° 20′ : 87° 16′), white Gondwana sandstones belonging to the Damodar series have been found to yield a sand which, after crushing, washing and sieving, is suitable for the manufacture of glass of ordinary quality (2). The sandstone is being quarried close to the bank of the Ganges by the Rajmahal Quartz Sand and Kaolin Co.; the stone is easily crushed and is then washed, the kaolin matrix and sand being recovered separately. There is little question that the supply from here could be readily increased. An analysis of the Patarghatta sand is given in Table 16.

TABLE 16.—*Analysis of sand from Patarghatta.*

SiO_2	96·00
Al_2O_3	1·15
Fe_2O_3	trace
CaO	trace
MgO	trace
Alkalies and water	2·85
TOTAL	100·00

Certain sandstones from the Talchir series on the Bokaro coal-field have also been suggested as suitable for glass purposes.

Some of the Vindhyan sandstones are a possible source of glass sands. The top stage of the Upper Kaimur sandstone in the adjacent Chakia district (Benares State), United Provinces, is a white quartzite low in iron oxides. Seven specimens collected from Chakia district by Mr. Auden, of the Geological Survey, were examined by Dr. A. Nadel, glass technologist to the Government of the United Provinces, and found to have an average of 0·056 percent ferric oxide. Six of these specimens averaged 0·038 percent ferric oxide. The same quartzites continue into Shahabad district and form the top of the Kaimur plateau. Auden also considers it probable that part of the Lower Kaimur sandstone, along the Son valley west of Dehri-on-Son and south of latitude 24° 50′, is also a potential glass-sand rock. This sandstone, over quite a wide area, is white in colour and has been extensively desilicated, thus rendering it friable so that it is easily crushed. The rock is even-grained, with a grain size averaging 0·4 mm. Investigation of its suitability for glass-making appears to be eminently desirable. These rocks occur just above the Rohtas limestone.

Distributed throughout the Archean sedimentary rocks in Gaya, Monghyr, Hazaribagh, Ranchi, Manbhum and Singhbhum districts, there are many extensive occurrences of fairly pure quartzites. The possibilities of the use of any one of these quartzites for glass-making purposes depend entirely on crushing costs. In certain cases it is possible that higher costs involved in crushing such a rock may be compensated by cheaper fuel, lower freight charges or availability of an extensive local market.

In addition to quartzites there are in certain parts of Bihar veins of quartz of very high purity. These could be definitely relied upon to provide quartz almost completely free from impurities. Here again, however, crushing and sieving charges will be heavy, but where a very high quality of glass is required it may be found possible to use such vein quartz. Large quartz veins occur in the Singhbhum granite, and others occur in Ranchi, Manbhum, Hazaribagh, Santal Parganas and Monghyr districts. Along the mica belt quartz from the mine workings is thrown on the dump heaps, and in some cases is quite pure.

Soda.

Most glass manufacturers in India use a mixture high in soda, as the resulting glass has a low melting point and is easy to work.

Soda carbonate, known as soda ash, has in the past been imported; it is available from the alkali works in Dhrangadhra State, Kathiawar. Both sodium carbonate and sodium sulphate are obtained as a surface efflorescence in North Bihar.

Limestone.

Limestone of good quality, suitable for the manufacture of glass, is obtainable within the province both from the Vindhyan limestones at Rohtas, and from the limestone deposits extending west from the Bokaro field into Palamau.

Manganese.

Excellent manganese deposits, with some chemical grade ore, have been worked in South Singhbhum. The supply of the highest quality ore has, however, become very limited from here, but will be available from Keonjhar State.

Future.

It is apparent that, in Bihar, the materials are available in abundance for the manufacture of the commoner varieties of glass and that it may even be possible to manufacture the better qualities providing the purer forms of quartz can be economically used. In the location of such an industry the choice of site, requiring the minimum transport costs on raw materials and finished articles, is important. The establishment of the industry at three centres, Jamshedpur, Dhanbad, and Patna would appear to have promise of success.

There is scope for considerable research on the raw materials and on the methods of manufacture of glass in the province. Much will depend on the actual encouragement of the Bihar people to make greater use of locally made glassware for a widening variety of purposes. As the industry expands it is to be hoped that there will be cooperation between the various firms, leading towards mutual improvement of methods and quality of product.

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CHAPTER XIX.

GOLD.

General.

As far back as history and tradition goes, gold has been washed from the alluvium along the rivers and streams of southern Chota Nagpur, mainly in Singhbhum and Manbhum, within the watershed of the Subarnarekha ("golden streaked") river. Even today after heavy rain the villagers close to certain streams average perhaps one to two annas per day by washing the river and stream sands at points which, by experience, they have found to be the most favourable. This work seems to be more frequently done by the women.

Auriferous quartz veins were also worked centuries ago by the then inhabitants of southern Chota Nagpur. The remains of their underground workings may still be seen in the jungle, and the crushing and rubbing stones which they used to grind the ores are frequently found (13). For these implements, either a hard trap or a hard fine quartzite was used, and they are similar to the implements used by the ancient copper workers. Possibly the same people mined the two metals.

Gold was found in the Sonapet valley (22° 53′ : 85° 40′) in the southeast corner of Ranchi district on the Singhbhum border in 1888, and during the resulting boom in 1890-91, thirty-two companies were floated with an aggregate capital of nearly one million pounds, but it was not long before all of these companies went into liquidation. The ruins of the mine buildings erected in the valley, and overgrown with jungle, still stand as monuments to misplaced optimism. The alluvial gravels and small quartz veins in this valley were too low in grade to sustain any highly capitalised company.

In Singhbhum, at Pahardia (22° 30′ : 85° 12′), some gold-bearing veins were opened up in 1901 for a short time, but it appears that the work was abandoned before the deposits were properly developed.

In 1916, gold was produced by the Dhalbhoom Gold and Minerals Prospecting Company, Ltd., at Kundarkocha (22° 28′ : 86° 15′),

in Dhalbhum (12). The total capital invested was Rs. 4.42,807, but mining ceased in 1919 after gold was produced to the value of Rs. 3,75,179-11-7, and dividends were paid in 1917 and 1918. The lease of this area was taken over by Mr. E. O. Murray in 1924, who has worked one of the deposits intermittently since, as opportunity offers.

TABLE 17.—*Production of gold.*

Year.	Bihar.		India.	
	Ounces.	Rupees.	Ounces.	Rupees.
1929 . . .	30	1,500	363,869·4	2,06,64,268
1930 . . .	30	1,500	329,232·3	1,86,85,211
1931 . . .	—	—	330,488·8	2,08,01,943
1932 . .	50	3,650	329,681·7	2,53,51,438
1933 . . .	267	19,738	336,106·3	2,76,40,071
1934 . .	114	8,323	322,142·9	2,92,71,130
1935 . . .	33	2,906	327,652·5	3,01,01,775
1936 . . .	82	5,004	333,385·6	3,06,02,413
1937 . . .	26	1,645	330,743·9	3,03,95,871
1938 . . .	16	996	321,137·8	3,04,75,397

In Manbhum gold-bearing veins have been worked near Lawa (23° 01′ : 86° 05′), Ichagarh (23° 02′ : 85° 57′) and Burudih (23° 02′ : 85° 51′) near Parkidi station on the Bengal Nagpur Railway. The lease of the Lawa deposit is at present held by Lowa Gold Mines, Ltd., whilst the veins near Ichagarh were worked by the Golden Reef Mining Syndicate but have recently been taken over by another interest.

Localities.

The principal rivers along which gold has been washed are: the Garra nadi in Dhalbhum, the South Koel in western Singhbhum, the Sanjai river in the Porahat, the Sona nadi in northern Singhbhum and the Subarnarekha river traversing Manbhum and Singhbhum.

Auriferous veins have been found in quite a number of localities. In Singhbhum at Pahardia (22° 30′ : 85° 12′) in western Singhbhum, Sausal (22° 37′ : 85° 17′) in the Porahat, the range of hills between Manoharpur station (22° 22′ : 85° 12′) and Ankua (22° 18′ : 85° 16′), Bhitar Dari (22° 42′ : 86° 11′), Digarsai (22° 35′ : 86° 15′)

and Kundarkocha (22° 28′ : 86° 15′). In Manbhum the deposits of Ichagarh and Lawa have been already mentioned. In Sonapet valley (22° 53′ : 85° 40′), Ranchi district, the alluvial gold was shed from quartz veins.

The copper veins at Nandup and Rakha Mines carried a little gold, and some gold-washing is still done there, but from the Mushabani lodes only a slight trace of gold can be detected in the copper ingots.

Geology.

A close acquaintance with the geology of southern Chota Nagpur leads to the conclusion that the gold-bearing veins are not entirely haphazard in their occurrence. These veins appear to occur only within a certain stratigraphical zone of schists which directly underlies the Dalma lava flows, and this zone of schists should be the principal guide to future prospecting. These schists occur on either side of the lavas which strike east and west across Singhbhum, Ranchi and Manbhum—stratigraphically these schists belong to what has been called the 'Iron-ore Stage'.

At Pahardia (22° 30′ : 85° 12′) the gold is associated with thin veins of white quartz which penetrate an earlier blue pyritic quartz. Hatch obtained an average yield of 4 dwt. from 6 samples taken from several of the veins (6).

At Sausal (22° 37′ : 85° 17′) the gold occurs with argentiferous galena in a few thin irregular stringers of quartz, penetrating chloritic phyllite. According to Maclaren the best samples showed only 2 dwt. of gold per ton and only one ton of quartz was in sight (8).

At the Porojarna mine, Kundarkocha (22° 28′ : 86° 15′), the gold is associated with a dark bluish grey variety of quartz, often seamed with white quartz. The country-rocks are sericitic and graphitic phyllites partly replaced by chert. The schists have been folded into a steeply pitching monocline, widening in depth. Six veins have been formed within the monocline, the veins being parallel with the folding. The veins average 2 to 3 feet in width, but may vary to as much as 15 feet. Besides occurring in the quartz the gold is found also in the phyllites along the walls (11, pp. 134-136). The gold content averages, perhaps, 4 dwt. Other adjacent quartz veins have also been worked.

At Lawa the quartz veins may be traced for ¾-mile in quartzite, quartz-schist and phyllite along the southern side of a low ridge.

Assayed samples vary from 2 dwt. up to one ounce, but the average is said to be less than 6 dwt. per ton. Copper is also present, and recently telluride has been recorded. Apparently the ore is complex and would require careful treatment. If the report is true that the gold is present as a telluride, roasting may be necessary before extraction.

The Ichagarh occurrence has not been geologically investigated, but it is apparently a simple ore, the gold being readily susceptible to extraction by amalgamation after crushing in stamp batteries.

Future.

The importance of the gold occurrences in southern Chota Nagpur should never be unduly stressed. It is clear that there are no gold deposits which would offer scope for the activities of any mining company with large capital. There is, however, still room for small prospectors and perhaps even small syndicates. Intelligent prospecting may bring to light new veins; such prospecting should be concentrated on the zone of schists underlying the lavas of the Iron-ore Series. These schists occur as a belt on either side of the flows which strike west to east along the northern border of Singhbhum and the southern border of Ranchi and Manbhum. There is also a belt of them striking northwest along the southern border of Dhalbhum from Kundarkocha (22° 28′: 86° 15′). Similarly, the belt of schists extending from Hakegora (22° 42′: 86° 10′) to Binburu (22° 40′: 86° 12′) and southeast of Digarsai (22° 35′: 86° 15′) deserves attention. In every case prospecting should be confined to the so-called blue quartz, and wherever this is absent it is useless to continue. But no certain prospects of valuable veins can be provided.

Washing for alluvial gold is likely to continue as an intermittent occupation of the villagers in certain localities. There is little probability that alluvial deposits will be found such as would pay a company to sluice on modern methods. The values quoted by Maclaren of 1 to 2 grains of gold per cubic yard in the Sonapet valley would be payable under certain conditions of topography, rainfall and depth of alluvium. But in the Sonapet valley the thin alluvium with rocky outcrops is not conducive to sluicing on a large scale with low costs, and any attempt to do so must be condemned at once.

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CHAPTER XX.

IRON-ORE

General.

Bihar is the most important province for the production of iron-ore in India. Even before the introduction of the modern smelting industry in India, indigenous iron-smelters were perhaps more flourishing in Bihar than in any other part of the country. Full accounts of the history of iron-smelting in India have been given from time to time, the more recent accounts are by Fermor (2), Jones (6, pp. 225-229) and Dunn (8, pp. 184-186).

Indigenous smelting, which was widespread in Chota Nagpur up to the close of last century and is even seen occasionally in the more inaccessible jungle tracts to-day, made use of several types of ore depending upon the locally available material--magnetite concentrates in river sands, laterite, ironstone concretions in Gondwana rocks, magnetite and hematite associated with the Archean rocks.

Although modern iron-smelting in India was founded on such deposits as the ore in the Ironstone-shales of the Gondwanas, supplemented by magnetite and hematite collected from small deposits in Manbhum and Dhalbhum, the rapid expansion since 1919 has been due to the opening up of vast hematite deposits in southern Singhbhum.

The Tata Iron and Steel Company founded its industry on the iron-ore discovered in 1904 by Mr. P. N. Bose of the Geological Survey of India, at Gorumahisani in Mayurbhanj State. A site for the erection of smelters was chosen close to the junction of the Subarnarekha and Kharkai rivers, and this jungle-clad site has since developed into the extensive modern town of Jamshedpur, with a population of about 100,000 people. The first blast furnace came into operation in November 1911, and four additional blast

furnaces have since been erected. Other industrial concerns have also been established around Jamshedpur, such as the Tinplate Company, Agricultural Implement Company, Indra Singh and Sons, Ltd. (wire works), and the Indian Cable Company. These industries centred around Jamshedpur have played a very important part in the industrial development of India during the last 20 years.

In 1907, the late Mr. R. Saubolle, who was prospecting for Messrs. Martin & Company, managing agents for the Bengal Iron and Steel Company, brought limonite and other iron-ore specimens from Notu Buru and Buda Buru in Saranda, Singbhum, to Dr. (now Sir) L. L. Fermor, who was at that time curator of the Geological Survey. The importance of these high-grade specimens was realised, and the company obtained mining leases over these areas. In 1910 ore was despatched by the Bengal Iron and Steel Company from Pansira Buru (part of Notu Buru) to the smelters at Kulti in Bengal. Further prospecting led to the discovery of great deposits of iron-ore in southern Singhbhum and in the States to the south, leases of which were taken up by the Tata Iron and Steel Company, the Bengal Iron and Steel Company, the Indian Iron and Steel Company, Bird and Company, and others.

Although the Notu Buru and Buda Buru deposits had been opened up by a mineral narrow gauge line from Manoharpur on the main Bengal Nagpur Railway, the deposits to the south and south-east remained inaccessible. Accordingly, in 1919, the construction of a branch line from Amda (now Raj Kharsawan) was commenced, the new line tapping such deposits as Noamundi, Gua and others south from Jamda. This line was completed by 1924. New projects are now under consideration to extend the line southwards, into Keonjhar, to tap further rich deposits.

The Tata Iron and Steel Company, until the cold weather of 1926-27, had obtained their iron-ore from Mayurbhanj State, but since that year the Noamundi deposit in Singhbhum has provided a large part of their requirements.

The production of iron-ore from this area during recent years is given in Table 18.

TABLE 18.—*Production of iron-ore.*

Year.	Bihar.		India.	
	Tons.	Rupees	Tons.	Rupees.
1929	(*a*)2,337,344	61,91,309	2,430,136	64,98,292
1930	(*a*)1,783,742	46,29,600	1,849,624	48,72,527
1931	(*a*)1,599,386	40,78,916	1,624,881	41,58,737
1932	(*a*)1,744,247	38,71,401	1,760,500	39,19,769
1933	(*a*)1,154,396	22,11,875	1,228,625	24,97,914
1934	(*a*)810,547	13,32,381	1,916,918	29,71,799
1935	(*a*)1,155,965	18,09,413	2,364,297	35,50,327
1936	1,375,214	22,22,580	2,553,247	40,17,134
1937	1,587,362	27,30,077	2,870,832	45,86,478
1938	1,421,090	26,89,996	2,743,675	45,56,964
1939	1,543,934	29,34,779	3,166,074	51,43,628

(*a*) Includes production of Eastern States.

Iron-ores of the Kolhan, South Singhbhum.

The Geological Survey of India, in 1919, commenced the mapping of this great iron-ore tract and extended the survey to a very large part of southern Chota Nagpur. Several memoirs on the region have appeared, by Jones (6) and Dunn (3, 8), that by Jones being more especially concerned with the rich deposits of southern Singhbhum and Keonjhar. In addition, detailed accounts of the Noamundi mine have been written by Percival (5, 9). More recently Dunn has revisited the area between Noamundi and Gua leading to a revision of earlier views on the stratigraphy (10).

The iron-ores of Singhbhum are associated with a group of rocks which were termed by Jones the Iron-ore Series. These rocks occupy steep sparsely inhabited forest-covered hills, the tops of which form the remains of an old peneplain at about 2,000 feet above sea level and were presumably at one time continuous with the Ranchi plateau to the north. Higher ridges, consisting mainly of banded hematite-quartzite, rise to nearly 3,000 feet.

The Iron-ore Series consists mainly of phyllites, tuffs, lavas, banded hematite-quartzites, and cherts. The iron-ores are more particularly associated with the banded hematite-quartzites of which they represent enriched portions. The banded hematite-quartzites crop out as ridges arranged in the form of a narrow horseshoe with closed end to the south in Keonjhar and Bonai, and with sides about 8 miles apart open to the northeast in Singhbhum. Other subsidiary outcrops of banded hematite-quartzite occur within the horseshoe and also to the west—it was one of the latter deposits at Pansira that was first discovered. The ridge forming the western side of this horseshoe is known as the Iron-ore Range. which is persistent for some 30 miles.

The origin of the banded hematite-quartzites has been discussed by Jones (6), Percival (5) and Dunn (3, 7, 8 and 10), but all are agreed that the bulk of the ore, particularly of the hard massive ore, has been formed by enrichment within banded hematite-quartzite, enrichment within phyllites being less important. Irregular distribution of the ore is due almost entirely to irregularity in enrichment of the banded quartzites, and very rarely to faulting.

In addition to the Iron-ore Series there is, in southern Singhbhum, a much younger group of rocks which Dunn has called the Kolhan Series. This consists of a basal sandstone-conglomerate overlain by limestones and shales. Locally, in the neighbourhood of the iron-ores within the Iron-ore Series, the Kolhan basal conglomerate is made up of material shed directly from the adjacent iron-ore, and this conglomerate is itself in places so rich as to be mined as iron-ore. An important deposit belonging to this later group of rocks is that at Jhiling Buru, south of Gua.

Debris from the iron-ore deposits is strewn down the steep hill sides, and such debris is frequently so abundant and so easily mined that it forms a very cheap source of ore indeed. Sometimes such ore has been consolidated at different levels, usually along valleys, and is known as *Canga.*

Practically the whole of the ore is hematite, only a very little magnetite can be detected under the microscope although it is apparent that magnetite was formerly much more abundant in the ore but has been replaced by hematite. The ores formed by enrichment within the Iron-ore Series rocks have been divided into various

types: massive ore, soft or porous shaly ore, 'blue dust', slump-ore. Massive ore has been formed by complete local enrichment of the ferruginous rocks. Soft or porous shaly ore has been formed by desilication or leaching out of silica from the banded hematite-quartzite; in some cases it represents an enriched ferruginous shale. "Blue dust" occurs where there has been almost complete removal of silica from banded hematite-quartzite without any cementation of the remaining hematite grains, which are left as a loose powder. Slump-ore, or breccia-ore, represents either local patches of acute disturbance by folding or faulting, or sometimes the brecciation of iron-ore beds in consequence of slumping following removal of material in solution from below.

Reserves and analyses.

Within the Kolhan Estate, Jones has estimated that a minimum of 1,000 million tons of ore, averaging not less than 60 percent iron, crops out at the surface. If the adjacent Eastern States are included, the minimum estimate is about 3,000 million tons.

The Kolhan iron-ores usually contain up to 64 percent iron, rising in exceptional samples to 68 or 69 percent, with phosphorus ranging from 0·03 to 0·08, rising in some cases to as high as 0·15 percent. The sulphur content is usually below 0·03 percent. A very little titanium is occasionally present. The main features of the ore, then, are high iron content, low sulphur and titanium, and variable phosphorus content. Manganese in any quantity is present only in the lateritic ores. On the whole the ores are high in alumina relative to silica, but in occasional selected ores silica may be higher than alumina.

An average analysis (on dry basis) of ore sent from Noamundi in 1937-38 was as follows:—

	Ordinary grade. Percent.	Hard ore. Percent.
Fe	60·80	65·51
SiO_2	2·39	0·75
Al_2O_3	4·93	1·20

A complete analysis of an average sample of Noamundi ore taken from a day's run is given in Table 19.

TABLE 19.—*Complete analysis of Noamundi ore.*

	Per cent.	
SiO_2	2·42	
FeO	2·45	(Fe 61·94)
Fe_2O_3	85·87	
Al_2O_3	4·31	
TiO_2	0·34	
MnO	0·11	
MgO	0·17	
CaO	0·35	
ZnO	*nil*	
PbO	*nil*	
CO_2	0·43	
Total alkalies	0·10	
Cr_2O_3	*nil*	
V_2O_5	*nil*	
CuO	0·010	
WO_3	0·004	
NiO	*nil*	
CoO	*nil*	
P_2O_5	0·188	(P=0·082)
SO_3	0·024	
As_2O_3	*nil*	
Combined water	3·26	

Other parts of Chota Nagpur.

Small deposits of iron-ore of a similar nature to those in the Kolhan occur in other parts of southern Chota Nagpur, such as to the southwest of Saruda (22° 38′ : 85° 12′) and in the hill range of Lukud Buru (22° 40′ : 85° 27′) in the Porahat (3) ; north of Kudlun (22° 47′ : 86° 23′), between Asanpani (22° 46′ : 86° 27′) and Basadera (22° 40′ : 86° 30′), near Hakegora (22° 42′ : 86° 10′) and east of Binburu (22° 40′ : 86° 12′) (8), in eastern Singhbhum; near Asanpani (22° 46′ : 86° 27′) and Tamakhum (22° 59′ : 86° 35′) in Manbhum.

The deposit at Hakegora was at one time worked by the Bengal Iron and Steel Company, but all of the above deposits are nowadays too small to be mined as iron-ores in competition with the enormous deposits of southern Singhbhum. However, some of the Porahat

occurrences are of micaceous hematite, especially that on Lukud Buru, and it is possible that other special uses may be found for them in the future, such as for particular kinds of paint.

In addition to the hematite-ores, deposits of magnetite have been mined in Singhbhum : near Kudada (22° 42′ : 86° 12′), east of mile 6 on the Haludpukhur-Jamshedpur road, and near Pathar-ghara (22° 32′ : 86° 27′) (8). The two former consisted of small veins or segregations in altered igneous rock and have been worked out. The deposits at Patharghara consist of magnetite associated with apatite, forming veins in granite-schist and other schists, and were worked at one time by the Bengal Iron and Steel Co., Ltd.; owing to the high phosphorus content this ore was useful for the smelting of foundry pig-iron. It is not at all improbable that the mining of these high phosphorus magnetites may be resumed in the future for the manufacture of high phosphorus pig-iron. In Man-bhum a deposit of magnetite has been recorded at Teludih (23° 34′ : 86° 57′) near Beharinath (1, p. 46).

In Palamau outcrops of magnetite occur on Gore Pahar (23° 58′ : 83° 58′), about 7 miles southwest of Daltonganj. The magnetite is associated with tremolite-schist, calciphyre (75 percent $CaCO_3$, 15 percent $MgCO_3$, 5 percent SiO_2 etc.) and granite. The structure of the hill is synclinal, and Auden estimates that the reserves of magnetite are of the order of 300-400,000 tons. The content of metallic iron averages 65 percent in the richer ore, but is much less in those tremolite-schists which have been only partially replaced by magnetite. In view of the abundance of high-grade hematite ore in Singhbhum it is unlikely that there will be any demand at present for this ore, unless for special purposes. A small deposit of coarse magnetite has also been recorded, by Dey, at Sua (24° 00′ : 84° 06′), 4 miles southeast of Daltonganj.

Titaniferous iron-ore, usually an intimate mixture of ilmenite, magnetite and hematite, has been found in southern Dhalbhum, around Dublabera (22° 29′ : 86° 17′) (8) and W. N. W. of Man-bazar (23° 03′ : 86° 43′) in Manbhum (1, p. 47). The treatment of this ore presents difficulties and there is no inducement to mine the deposits. Owing to its vanadium content the Dublabera material may come into use some time in the distant future. The latter deposits are described in Chapter XXXIV.

On the Raniganj, Jharia, Bokaro, Ramgarh, Karanpura and Auranga coalfields, lenticles and nodules of iron-ore, which were at

one time used by indigenous smelters, are not now mined as a normal source of iron-ore in view of the rich and enormous deposits in southern Chota Nagpur. However, it is always possible that ores of this type, possessing special properties, may have a small demand from time to time, *e.g.* a certain amount of soft limonitic ore is used as a desulphuriser in coking and gas plants.

With this latter proviso it may be apposite, perhaps, to complete this note with the advice that iron-ore deposits of value are unlikely to be found in the future in this province outside of Singhbhum. If any such deposit were found it would be economically attractive only if the ore possessed some special property either in smelting, or for some other purpose apart from its use for pig-iron.

Mines in South Singhbhum.

The two main companies now mining iron-ore in South Singhbhum are Tata Iron and Steel Company and Indian Iron and Steel Company.

Tata Iron and Steel Company.—This company mines ore not only at Noamundi, in Singhbhum, but also in Mayurbhanj and Keonjhar States. The Noamundi ore-bodies occur in two parallel north-south ridges, each about two and a half miles long. These ridges are, for the most part, covered by jungle, and the surface is also usually deeply covered by laterite and float ore or ore debris. At least 300 million tons are available here.

Percival divides the ore into several types :—

1. Hard massive dense ore, usually of great purity.
2. Soft crumbly or "biscuity" laminated ore, often somewhat high in silica content.
3. Soft shaly ore, tending to become high in alumina.
4. Powdery ore, or "blue dust", so fine that 40 percent will pass through a 200 mesh sieve.

The ore is mined and loaded into tubs mainly by contractors who pay their miners on a volume basis. Hard ore is drilled by a separate staff, also under contractors, and drilling is paid on a footage basis. Blasting is carried out by the company's staff. Working faces do not exceed a height of 30 feet for safety reasons. Fines, which cannot be sent to the smelter, are dumped away from the ore-body; they contain about 53 percent of iron and may, in the future, be sintered for smelting.

The number of coolies (men and women) employed varies widely, averaging perhaps 2,000-2,500, the maximum being 7,000 in any one year. In 1938 the average production per head for the contractor's miners was 1·09 tons per day, and 1·38 tons per day for labour employed by the company.

The ore is railed to the main crushing and loading plant; the total length of track on the mine is about 20 miles. The ore is crushed to 3-inch maximum size through either a No. 25 A Telsmith gyratory crusher, 325 tons per hour capacity, or a No. 5 Symons cone crusher, 450 tons per hour capacity. These feed direct to the trucks on the broad-gauge Bengal Nagpur Railway siding. Every wagon is sampled at the mine and the quartered samples from each train are sent with the train to Jamshedpur for analysis. The annual productions of ore at Noamundi mine since operations commenced in 1926 are given in Table 20.

TABLE 20.—*Production from Noamundi mine.*

Year.	Tons.
1926	156,425
1927	507,580
1928	415,761
1929	461,529
1930	391,508
1931	415,929
1932	528,370
1933	469,114
1934	499,163
1935	526,022
1936	586,430
1937	681,157
1938	605,141
1939	783,799

Indian Iron and Steel Company.—This company's mines include the deposits at Pansira Buru and Buda Buru, which originally were the property of the Bengal Iron Company, and also the deposits at Gua.

The Pansira Buru deposit, situated 12 miles southeast from Manoharpur on the B. N. Railway, is now almost exhausted. The reserves formerly amounted to about 10 million tons. An aerial ropeway with a capacity of 40 tons per hour transported the ore from the hill top to a bin at the foot where it was loaded into wagons and hauled over the 2-foot 6-inch gauge railway to Manoharpur.

The Buda Buru deposit is situated 8 miles southeast of Manoharpur. The reserves amount to at least 150 million tons and the ore is high-grade, averaging 64 percent iron. The ore is brought by gravity incline down the hill to the foot, the capacity of the incline being 60 tons per hour.

The Gua mines are served directly by a branch line of the B. N. Railway which terminates at Gua. The deposits here contain at least 100 million tons of ore and are developed to a capacity of 60,000 tons per month. The main deposits are on the high ridge to the west of Gua and the ore is brought from a bench part way up the hill to the bins along the railway at the hill foot by aerial ropeway, the capacity of which is 120 tons per hour. The ore from the ridge top is fed to the ropeway by self-acting inclines. Another deposit, on Jhiling Buru, occurs immediately to the south of Gua; the ore is lowered by inclines to the crusher level and loaded directly into the B. N. Railway wagons. Recent production of iron-ore from the Singhbhum mines of the Indian Iron and Steel Company is given in Table 21.

TABLE 21.—*Iron-ore production of Indian Iron and Steel Co., from Singhbhum.*

Year.	Tons.
1936	788,784
1937	901,124
1938	778,793
1939	715,651

Iron and Steel Works at Jamshedpur.

The ore from the iron-ore mines of Tata Iron and Steel Co. is railed to the smelters at Jamshedpur, in Bihar, whilst that from the mines of the Indian Iron and Steel Co., is taken to the smelters at Kulti and near Asansol in Bengal.

Jamshedpur was chosen as the site for the steel works as it is alongside the main B. N. Railway, is mid-way between the iron-ore fields and coalfields and within easy railway reach of large limestone deposits, and is also close to a plentiful supply of water. Since its inception, the town has become one of the greatest iron-smelting centres in the British Empire.

Five blast furnaces are now in use, capable of producing over a million tons of pig-iron a year. About three-quarters of this is

used in the manufacture of steel, and is hauled in a molten state in 60-ton ladles by locomotives to the open-hearth and Duplex steel-making plants.

The open-hearth plant has a capacity of 1,000 tons per day, whilst the Duplex plant is capable of producing 2,000 tons per day. In the open-hearth process the charge consists of molten pig-iron and steel scrap from the rolling mills, and is heated by producer gas; impurities are removed by adding lime and iron-ore. The steel is cast into 5-ton ingots. In the Duplex process molten pig is charged into 25-ton acid-lined Bessemer convertors, and part of the impurities removed by blowing air through the molten metal. It is then transferred to 200-ton basic-lined tilting furnaces where it is further purified and adjusted to the necessary composition, then poured into a 130-ton ladle and cast into 5-ton ingots.

The rolling mill plant consists of a 40-inch blooming mill in which the ingots are reduced to blooms and slabs of various dimensions; these are then rolled into billets, bars, sleeper plates, flats, heavy structural sections, beams, channels, angles, tees and plates. Sheet mills produce up to 110,000 tons of galvanised and black sheets per annum. A pressed-steel sleeper plant can turn out 20,000 tons of steel sleepers annually.

All these mills are electrically driven. The power house capacity is 37,500 kilowatts, providing power not only for the plant but for the town service and for other factories such as the Tinplate Company, and the Indian Cable Company. The boilers are fired by waste gases from the blast furnaces. In addition there is an extensive coking plant, with by-product recovery of tar, ammonia, and fuel gas, the ammonia being converted into sulphate by means of sulphuric acid made at the works from imported sulphur.

Future.

The growth of India's iron and steel industry in the future will depend largely on India's capacity to absorb the metal, as industry in general expands. There is little or no scope for export of iron and steel from India in great quantities, competition is keen and neighbouring industrial countries, Australia, Africa and Japan are equally capable of turning out their own requirements. Japan, although she has a well-organised iron and steel industry, is deficient, however, in resources of high-grade iron-ore. India, in normal times, could supply large tonnage of iron-ore to Japan but the

profit of the trade in this raw material is extremely low, amounting to only a few annas per ton. The real value of iron-ore, to any country, is not in the money value of the ore itself, but in the ultimate value of the metal produced and the great industry to which it gives rise within the country. The iron and steel industry, in India, is in vigorous capable hands and may be safely left to develop and expand as opportunity presents itself.

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CHAPTER XXI.

KYANITE.

General.

In recent years the mineral kyanite, a silicate of alumina ($Al_2O_3.SiO_2$), along with its chemically equivalent minerals, sillimanite and andalusite, has come into prominence because of its value for certain purposes in the ceramic industries.

On heating clay-ware in the manufacture of porcelain and fire-brick, the clay is largely converted into mullite, $3Al_2O_3.2SiO_2$. This led to the opinion that a natural mineral high in Al_2O_3 would be most useful in the manufacture of such ware, providing a more refractory product, and experiments were conducted on the use of sillimanite, kyanite and andalusite. It was found that, on heating to 1545°C, these minerals also change to mullite plus a siliceous liquid. If additional Al_2O_3 is present in the form of, say, corundum, up to the point at which the total composition of the mixture is $3Al_2O_2.2SiO_3$, theoretically the whole should form mullite which begins to melt at 1810°C.

In using these minerals for ceramic and refractory purposes it has been found necessary first to calcine the raw material in order to convert portion of it into mullite. During this conversion the minerals undergo a change in volume, kyanite, particularly, expanding considerably on heating. This expansion, however, with its resulting shattering, considerably increases the ease with which the rock can be crushed before being manufactured into ceramic and refractory wares.

Deposits of these alumina silicates are not abundant, and are restricted to only a few countries. In India, sillimanite occurs particularly in Assam, and kyanite in Singhbhum and the adjacent State, Kharsawan. The deposit of kyanite at Lapsa Buru in Kharsawan is easily the largest known in the world.

The kyanite deposits of Singhbhum and Kharsawan have been known since 1907 from specimens submitted by Mr. Srinivasa Rao to the Geological Survey of India. They were later visited by officers of the Geological Survey of India, but as massive kyanite was not of economic value at that time the discoveries were not made public. Subsequent to 1923, when the deposits were examined

by the writer, there has been a gradual increase in their exploitation. The production from Singhbhum and Kharsawan during recent years is given in Table 22.

TABLE 22.—*Production of kyanite.*

Year.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1929	(a) 3,618	24,077	3,618	24,077
1930	(a) 8,641	1,31,505	8,641	1,31,505
1931	(a) 3,409	48,928	3,412	48,928
1932	(a) 5,580	91,227	5,580	91,227
1933	(a) 4,266	68,888	4,283	69,432
1934	(a) 9,378	1,42,610	9,411	1,43,113
1935	(a) 19,903	3,24,055	19,903	3,24,055
1936	(a) 24,787	3,53,178	24,787	3,53,178
1937	(a) 26,936	6,49,092	26,936	6,49,092
1938	830	19,818	28,385	6,80,169
1939	766	11,490	9,916	1,55,351

(*a*) Includes production of Eastern States (Kharsawan and Saraikela).

Composition.

The theoretical composition of kyanite is: silica 36·8 percent, alumina 63·2 percent but variable amounts of other impurities, such as quartz, rutile, magnetite, mica, and corundum, are usually present in most deposits of massive kyanite, so that analyses usually vary somewhat from this. Four analyses of kyanite-rock are given in Table 23.

TABLE 23. *Analyses of kyanite-rock*

—	Lapsa Buru.		Ghagidih.	
	Percent.	Percent.	Percent.	Percent.
SiO_2	35·4	32·48	36·0	34·66
Al_2O_3	61·4	65·05	60·7	60·84
Fe_2O_3	trace	1·57	2·3	0·07
TiO_2	n.d	0·52	1·2	1·18
CaO	3·1	0·65	0·8	..
MgO	n.d	trace	0·4	..
H_2O	n.d	0·24	0·9	0·90
Undetermined, including alkali	..	..	..	2·35
TOTAL .	99·9	100·51	102·3	100·00

Samples quite frequently analyse up to 68 or 69 percent of Al_2O_3, which invariably means that fine corundum is associated with the kyanite. This, of course, is advantageous, increasing rather the refractory character of the material. Fe_2O_3 is deleterious and tends to decrease the melting point, preferably it should not exceed 1·5 percent. CaO tends to have a fluxing effect. Alkalies, present if mica is associated, very seriously affect the suitability of the kyanite for refractory purposes by lowering the melting point.

Uses.

Kyanite has many uses in the ceramic industry, after it is converted into mullite by calcining. Mullite possesses the following properties which render it so valuable as a refractory: perfect stability up to its softening point, 1810°C; very low coefficient of expansion; great mechanical strength at high temperatures; equally suitable in both oxidising and reducing atmospheres; neutral as a refractory, resisting the corrosive action of most non-metallic slags and the abrasion of furnace charges; high electrical resistance; moderate thermal conductivity. It is used in porcelain spark plugs, and as practically the only constituent of certain ceramic products. It imparts great toughness and strength to the wares, and electrical porcelains in which it is used have a remarkably low conductivity. It is finding an increasingly wider use in refractory bricks, particularly where furnace conditions are severe, such as in boiler furnaces, combustion chambers, pottery kilns and glass furnaces. The calcined product is also used for the manufacture of pots, retorts, crucibles, saggars and muffles, gas fires, electrical refractories, etc. The action of glass melts in glass-house tanks and in glass pots is perhaps one of the severest tests to which any refractory could be subjected, and refractory material made from kyanite has proved most suitable. In metallurgical practice its use is limited by the fact that ferrous and other metallic oxide slags readily fuse it, but it may be used in those furnace parts away from the melt where resistance to high temperature alone is required, such as in the roofs of electric steel melting furnaces.

Localities.

Kyanite has been found to occur along a belt some 80 miles in length, stretching east from the western side of Karaikela Estate

(part of Saraikela), through part of northern Singhbhum, thence through Kharsawan and Saraikela States, and through Dhalbhum, turning southeast as far as Shirbai *dungri* (22° 21′ : 86° 40′). For the greater part of its length it follows the northern side of the Singhbhum copper belt.

Within this belt, easily the most important deposit occurs at Lapsa Buru (22° 48′ : 85° 44′), Kharsawan State, and is therefore outside of the boundary of Bihar. Other small deposits not within Bihar are in Karaikela, and at Jhar Gobindpur (22° 48′ : 86° 05′) in Saraikela. The principal deposits in Singhbhum are in the vicinity of Ghagidih (22° 45′ : 86° 11′), between Badia (22° 30′ : 86° 28′) and Bakra (22° 29′ : 86° 29′), near Kanyaluka (22° 28′ : 86° 31′) and at Mohanpur (22° 34′ : 86° 32′). Unfortunately the Kanyaluka material has rather a high iron content. The workable deposits in Singhbhum are being rapidly mined and will be completely exhausted within a short time.

The mineral has been found also at the following localities in Singhbhum: Rakha Mines east ridge (22° 38′ : 86° 22′), Shirbai, Singpura (22° 22′ : 86° 35′), near Chirugora (22° 33′ : 86° 31′), northwest of Dobha (22° 32′ : 86° 31′) and northwest of Bhakar (22° 23′ : 86° 36′), but massive kyanite-rocks suitable for mining have not been found at these places as yet. In addition, south and west of Daontanri (22° 30′ : 86° 09′), specimen segregations of both kyanite and andalusite have been found.

In Manbhum, small deposits of kyanite-rock occur along a narrow belt 7 miles in length, extending from Ichadih (22° 04′ : 86° 10′) to Salbani (23° 04′ : 86° 17′), but owing to the high percentage of mica present in the rock it is not suitable for refractory purposes.

Mode of occurrence.

All the Singhbhum occurrences of kyanite-rock are associated with kyanite-quartz-granulite and aluminous mica-schists. The kyanite occurs as segregations and veins in these rocks. Apart from a few deposits of massive kyanite in the schists near Lapsa Buru, and a small deposit at Ghagidih, most of the kyanite-rock is obtained as debris on the surface or in the soil. This kyanite debris, being extremely resistant to weathering, has been left behind subsequent to the weathering and removal of the enclosing softer schists and granulite. Usually such kyanite debris has suffered

little or no lateral transportation but has been left almost immediately at the site of the original occurrence of the rocks.

Other deposits may yet be found in the soil along the Singhbhum belt, but from the very nature of their occurrence huge deposits cannot be expected, and each can have only a relatively brief period of supply. The Lapsa Buru occurrence is, however, unique, not only in India but in any part of the world. In 1927 an estimate of the minimum amount present there down to a depth of 3 feet was 200,000 tons, but it was expected to exceed this amount many times. It is now being mined at the rate of over 30,000 tons per year without any noticeable exhaustion.

The kyanite-rock is massive, never cleaved, and is usually medium to coarse-grained. Hand specimens which appear to be quite fine-grained to the naked eye are found, under the microscope, to be of coarse crystals which are full of fine inclusions of corundum. Usually kyanite is almost the sole constituent of the rock. It is commonly of the radiating variety, and blades of crystals over 12 inches long may be sometimes seen in the large boulders. A very little rutile is usually present, and sometimes minute grains of magnetite. Tourmaline and topaz occur in places, and also pink dumortierite, the latter being particularly prevalent at Mohanpur. Neither topaz nor dumortierite appear to affect the refractory properties of the kyanite, as the fluorine and boron respectively are driven off in calcining and both minerals are then converted to mullite. Occasionally the green mica, euphyllite, is seen, but this lowers the refractory quality of the rock.

Future.

Although increased production from the kyanite deposit at Lapsa Buru, in Saraikela State, may be expected in the future, any increase from Singhbhum cannot be expected. The known useful deposits are either exhausted already or are approaching exhaustion. However, by carefully prospecting the soil in the vicinity of the beds of kyanite-quartz-granulite which occur in the mica schists, there is always the possibility of finding further deposits. In particular, the soil should be prospected on the opposite side to the dip of the quartz-granulite. It is also not at all improbable that the belt may be found to extend further west from its present known limit, in the Porahat, where the writer has seen specimens of kyanite-mica-schists.

Practically the whole of the kyanite produced is exported. Only a very little has been made into refractory bricks in this country, by Messrs. Burn and Co. at their Raniganj works. The question may have to be considered whether the greater part of the production should not be manufactured into refractory bricks and ceramic ware in this country, and the finished articles exported. The means and skill are available in the country, the main points are the difficulties of transporting the manufactured goods, and whether overseas markets will accept the Indian made finished article in preference to the raw material.

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CHAPTER XXII.

LEAD AND SILVER.

General.

Small deposits of lead-ore have been recorded from many scattered parts of Bihar from time to time. On various occasions from 1850 until early this century several of these deposits were opened up by syndicates and companies, but none of these attempts were successful. For the most part the optimism of the prospectors was completely unwarranted from the smallness of the deposits, presumably in consequence of lack of experience of what is required of such deposits in order that they should be commercial propositions. It is perhaps possible that in some cases the capital available was too limited, but the author is of the opinion that failure was entirely due to the absence of any deposits of reasonable size.

Perhaps the most serious attempt to open up a lead deposit in Bihar was made in 1904 and 1905 by Messrs. Mackinnon Mackenzie and Co. at Beldi (23° 03′ : 86° 18′) in Manbhum. The deposit, however, was confined to the surface and did not continue in depth. The ore was railed to Howrah and smelted in a small furnace at Shalimar. The total yield came to 91½ tons of lead, 4,716 ozs. of silver and 86 grains of gold, the sale of which just met the total expenses of mining, smelting, etc.

Like most lead-ores in all parts of the world, the majority of the ores in Bihar contain a certain amount of silver. The lead-ores consist mostly of the sulphide, galena, with a little carbonate, cerussite. In addition, the zinc sulphide, sphalerite, is sometimes present, and also copper pyrites. It is not clear whether the silver occurs as a distinct mineral, but it is probably simply in solid solution in the galena. Many of the ores contain a little antimony.

A full summary of the known information on this subject prior to 1891 may be found in the book by King and Pope on 'Gold, copper and lead in Chota Nagpur'. A summary up to 1921 is given in Fermor's 'Mineral resources of Bihar and Orissa'.

Localities.

The majority of the galena deposits of Bihar are grouped into two belts. One belt occurs across North Singhbhum and South

Manbhum in the southern part of the province. The other extends from Palamau district through Hazaribagh and South Monghyr districts into South Bhagalpur district and Santal Parganas, lying between the mica belt on the north and the Damuda valley coalfields to the south.

In Singhbhum, galena has been found associated with the auriferous quartz veins of Pahardia (22° 30′ : 85° 12′) and Sausal (22° 37′ : 85° 17′). Griesbach (10) recorded the discovery by F. Smith of an irregular galena vein, probably near Pahardia, a specimen of which assayed 79·3 percent lead, with 34 ozs. 2 dwts. 17 grs. silver and 11 ozs. 2 dwts. 3 grs. gold per ton of lead.

In Manbhum galena was first found at Janijhor near Dhadka (22° 48′ : 86° 30′) by Ball (5) in 1870. He found that the ore occurred as small lenticular masses 5 or 6 inches long in quartz veins in the schists. An analysis of a specimen showed 79 percent of lead, and 119 ozs. 4 dwts. 16 grs. of silver per ton of lead, but, of course, analyses of picked specimens give no indication of the likely average value of a deposit. In 1904 and 1905, whilst working the deposit at Beldi, Messrs. Mackinnon Mackenzie and Co. prospected galena deposits at Janijhor, Kushbani, Lata, Lewshai, Panra, Ghagra, Nanna and Dakia, all within a radius of 6 miles of the deposit at Dhadka first found by Ball. All occur in mica-schists, but were superficial and no continuous lode was found. This area was visited by Dr. A. K. Dey in 1934-35, who was unable to find any evidence which could lead to any alteration of opinion on these deposits. A little galena has been detected in barytes specimens from Malthol (23° 26′ : 86° 26′).

Specimens of galena have been recorded from Sili (23° 21′ : 85° 50′) in Ranchi district, whilst the mineral has also been found associated with the barytes at Silwai (23° 23′ : 85° 27′). A quartz vein containing a little galena was prospected some years ago at Kumbakera (22° 29′ : 84° 45′), but it is said that only 3 maunds of galena were obtained; according to Krishnan other veins are unlikely to be found (13).

In Palamau, Ball (8) recorded the finding of weathered fragments of galena on the surface near Barikhap (23° 59′ : 84° 49′), but the source of the mineral has never been located.

In Hazaribagh lead-ore was discovered at Hisatu (24° 00′ : 85° 01′) by Motte and Farquhar in 1777, and according to Hunter (7) was worked for antimony towards the end of that century.

The mine was rediscovered by Ouseley (3) in 1842, and specimens of the ore assayed 47·02 percent lead and 4·7 percent antimony with no trace of silver. No further investigation appears to have been made.

A lead mine is indicated at Nyatand (24° 30′ : 85° 43′) on Sherwill's map of Bengal (4), but no particulars appear to have been obtained.

Galena was found associated with the copper-ore at Baragunda (24° 05′ : 86° 04′), and Mallet (6) recorded its association with disseminated copper in the Patru stream at Mahabank northeast of Golgo (24° 24′ : 86° 22′). An unsuccessful attempt to mine the latter was made in 1880; the promoters absconded.

Surface fragments of cerussite have been recorded by Mallet (6), from near Mehandadi and Baramasia (24° 20′ : 86° 16′) and near Khasmi and Nawadih (24° 29′ : 86° 22′). Rolled masses containing galena have also been found in the river alluvium near Parasiya (24° 10′ : 85° 48′). In none of these cases has any trace of the ore *in situ* been found.

Sherwill mentioned the occurrence of a vein of argentiferous galena in the Kharagpur hills, but gave no precise locality. Similarly, although galena has been recorded in the Chakai hills the exact locality is unknown.

In Bhagalpur, attempts were made to open up a galena deposit at Dudhijarna (24° 53′ : 86° 45′) in 1879 but there is no record of the result. A surface specimen was reported by Ball (8) to yield 71 percent lead with 42 ozs. 3 dwt. of silver per ton of lead. Lead-ore was said to occur in the same neighbourhood at Gonora, Karda and Kajuria. At Gauripur or Phaga (24° 46′ : 86° 56′) a shaft was sunk in 1878 to a depth of 30 feet on a vein of lead-ore. The average of three specimens showed 71·7 percent lead, and the silver content of one was as high as 103 ozs. 2½ dwt. of silver per ton of lead. A specimen of galena from Kharikhar (24° 50′ : 86° 45′) assayed 52 ozs. 8 dwt. 14 grs. of silver per ton of lead, but there is no other record of the occurrence.

In Santal Parganas, lead-ore has been recorded from Akasi or Panch Pahar (24° 38′. 87° 10′). McClelland (1) recorded that the lead-ore constitutes 2 percent of the rock mass, but Buchanan Hamilton described it as antimony sulphide. In any case the occurrence is valueless from the descriptions given. At Bhairukhi (24° 36′ : 86° 36′), lead and silver have been recorded as being

associated with the copper-ore which was at one time opened up by the Deoghar Mining Co. Large lumps of galena were also found on the surface about 150 yards S. S. W. of the copper mine, but on prospecting no further ore was found. A deposit of lead-ore is shown on Sherwill's map in the Sanka Hills (24° 17′ : 87° 19′): the exact locality is unknown, but Ball (8) suggested that it was on Chandipahar (" silver hill ") to the southwest of the main hills.

Future.

Notwithstanding the numerous localities mentioned in the extensive literature on the lead-silver occurrences of Bihar, the possibilities of starting a lead-smelting industry in this province appear to be *nil*. Although it is true that some of the occurrences have received little or no investigation, the type and history of the deposits recorded in the province have been such as to offer no hope of any of them proving to be successful mines from the modern point of view.

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CHAPTER XXIII.

LIMESTONE.

General.

One of the most useful raw materials in any country is calcium carbonate, limestone. India is well endowed with resources of this material and Bihar is fairly well supplied. Indeed, the earliest reference to the quarrying of limestone in modern times in India, in 1847, is to the limestone of Lower Vindhyan age at Rohtasgarh in Shahabad district. Mallet, in 1869, described the quarrying and lime-burning industry there and the transport of the lime *viâ* the Son river and Ganges. Since those days, the industry has gradually increased, not only in Shahabad, but in other parts of the province Cement factories have been erected in Shahabad and Hazaribagh districts. With the expansion of industrial activity and the further development of engineering in the province, the limestone and cement industry may be expected to continue to increase in importance. Some idea of the size of the industry is provided by the production figures given in Table 24.

TABLE 21.—*Production of limestone and kankar.*

Years.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1929	(a)889,499	(a)18,41,128	3,352,442	47,59,314
1930	(a) 842,210	(a)18,50,494	3,297,476	48,48,789
1931	(a) 663,424	(a)13,58,764	2,887,612	38,60,635
1932	(a) 629,745	(a)12,52,568	2,001,084	27,78,560
1933	(a) 705,598	(a)14,46,855	3,143,036	40,29,842
1934	(a) 877,854	(a)17,87,204	3,990,335	47,67,959
1935	(a) 1,035,315	(a)20,81,933	3,483,418	45,91,020
1936	(a) 329,926	(a) 4,38,173	3,451,833	44,35,4 3
1937	345,037	4,67,757	3,547,561	45,98,239
1938	613,138	8,44,147	3,953,973	50,70,505
1939	500,364	6,61,258	3,915,345	46,55,813

(a) Includes production of Orissa and Eastern States.

Uses.

The simplest use of limestone, including also marble, is as a building stone. However, in Bihar, little or no limestone is quarried at present for that purpose. Very large amounts of limestone are burnt annually for use by the building trade as lime for mortar and plaster. Much limestone is required as a flux in the iron and steel trade, but for this purpose the limestone generally used at Jamshedpur is obtained from more accessible deposits outside of the province. A certain amount of lime is necessary in the manufacture of glass. Very pure lime is required in the chemical industries, particularly in the manufacture of bleaching powder. It is also necessary in the manufacture of calcium carbide and calcium cyanamide; the latter is an important nitrogeneous manure which would find a market if available in India. Perhaps the largest amount is now used however, in the manufacture of Portland cement, which is made by fusing limestone with suitable clays. Recently, the manufacture in Bihar of *ciment fondu* or aluminous cement has also been projected, utilising local limestone and either bauxite or aluminous laterite.

Composition.

For use as building stone the composition of a limestone is immaterial—its durability, appearance, ease of working and price are the only considerations.

Limestones which are burnt to form lime, for use in mortar and plaster, need not necessarily be particularly pure, in fact in some cases certain clay impurities may improve the qualities of the burnt product for use as mortar. A very impure form of calcium carbonate is *kankar*, which occurs as a surface deposit in many parts of the province and is collected and burnt; the clay and other impurities are frequently in such correct proportions that the resulting hydraulic lime has practically the properties of cement.

For use in chemical industries a very pure limestone is essential. The presence of relatively chemical inert material like quartz is not particularly detrimental although its absence is preferred, but a high percentage of iron and alkalies is not permissible. The iron, if possible, should be below 0·20 percent, and the combined impurities less than 1-2 percent.

For the glass industry a high degree of purity is also essential. Free quartz is unimportant as also are the alkalies, as they enter

into the composition of the glass in any case, but magnesia and particularly iron are undesirable. The alumina content also should be low.

Limestones used in the iron and steel industry need not be low in magnesia and iron. Silica and alumina are the main impurities to be avoided for they add considerably to the slag formed in the smelter. At times, however, in smelting a high alumina iron-ore, say, a little silica in the limestone is permissible.

In the manufacture of cement considerable amounts of silica and alumina, within reasonable limits, are permissible in the limestone, for they have to be added to the kiln charge in any case, in the form of clay. However, they must not be so excessive as to make it impossible to adjust the limestone-clay mixture to that necessary for the composition of the required cement. Magnesia is undesirable in the limestone and should not be greater than 2·0 percent. Iron in the limestone should not normally exceed 2·0 percent. Alkalies are driven off in the flue gases and, indeed, provide a source of potash in some countries.

Distribution.

Archean.

White crystalline limestones have been quarried in a small way in the Archeans to the south of the Raniganj coalfield, in Manbhum district. One deposit half-a-mile west of Hansapathar (23° 38′ : 86° 40′) was reported to be 70 to 80 feet thick, only 3 to 4 feet being of good quality. North of the village a 25-foot band occurs, and a third deposit, 150 feet thick, occurs to the north of Asta village. These limestones were used in a small way during the early days of smelting at Kulti. Their composition is given in Table 25.

Table 25.—*Limestone from Hansapathar.*

	Percent.		Percent.
$CaCO_3$	83·43	$CaCO_3$	67·30
$MgCO_3$	0·78	$MgCO_3$	0·57
$FeCO_3$	0·68	Fe_2O_3	0·73
P_2O_5	0·02	Al_2O_3	0·09
Insoluble matter	16·18	Insoluble matter	31·31
	101·09		100·00

In Manbhum there are a few deposits of crystalline limestones in the Iron-ore Series. They occur at Kukru (22° 51′ : 86° 23′), Kultanr (22° 59′ : 86° 34′), Tamakhun (22° 59′ : 86° 36′), northwest of Kumari (22° 58′ : 86° 38′), Gobindpur (22° 58′ : 86° 39′), Mirgichanda (22° 58′ : 86° 41′) and southeast of Kantagora (22° 58′ : 86° 42′). They are usually small, the largest being at Tamakhun and northwest of Kumari; the former is 600 feet in length and 40-50 feet in width at the outcrop.

Isolated patches of limestone occur over a belt extending east and west parallel with the coalfields between Ramgarh and Palamau. These are associated with schists included in the granite-gneiss. Usually they dip at a steep angle and appear to persist to some depth. They are quarried at the surface, but in consequence of the dip the overburden increases considerably with depth. For the most part these limestones are low in magnesia but many are rather high in silica. Some of the pure white rock from near Olhepat (23° 50′ : 84° 44′), on the eastern edge of the Auranga coalfield, might be suitable for statuary marble. So far as is known the magnesia content seems to increase westward, and the outcrops west of the Koel river, such as at Ban Pahar in Semra mouza and near Sua (24° 00′ : 84° 05′), southwest of Daltonganj, are rather dolomitic and rather impure. Between Pandwa (24° 10′ : 84° 04′) and Majhauli (24° 10′ : 84° 08′), there are small bands of serpentine marble. Information about this belt of limestones is rather meagre although individual deposits are fully known to the lessees. They are now being worked at quite a number of places, and cement is being manufactured at Khalari. The Tata Iron and Steel Company are also quarrying limestone near Bakoria, about 20 miles southeast of Daltonganj.

The writer is indebted to Dr. Henry Day for the following information on the limestone areas being worked along the Damodar valley west of Ramgarh.

Bundu-Basaria (23° 40′ : 85° 23′—85° 26′) in Ramgarh Estate Hazaribagh district. The limestone zone strikes east-west with a width varying from 500 to 1,200 feet. It is well exposed over wide areas of undulating ground, largely under cultivation. Schists are interbedded, but thick sub-zones of good limestone are available for development, which dip steeply to the north and are overlain

by a considerable thickness of a very impure limestone. The quality of the limestone (on the basis of insolubles) varies widely from sub-zone to sub-zone across the strike, but the quality along the strike of each zone appears to be fairly constant. Large reserves are available for the manufacture of lime and cement. At present the limestone is being developed in a minor way for local lime manufacture by the Karanpura Development Co., Ltd. Dolerite dykes cut the limestone.

Kurkuta-Religara (23° 43′ : 85° 21′- 85° 22′) in Ramgarh Estate, Hazaribagh district. The strike of this zone varies from east-west to northeast-southwest, and the dips are high to the north and northwest. Schists are interbedded between thick sub-zones of good limestone, and the main limestone sub-zone is succeeded by a thick group of calcareous schists. The average quality of the limestone is superior to that at Bundu, and there are large reserves for the manufacture of cement and lime or for use as flux. The area has been prospected by Karanpura Development Co., Ltd., and has not yet been developed.

Lapanga-Bhurkunda-Kursa (23° 38′ : 85° 21′--85° 23′), in Ramgarh Estate. The direction of strike is variable but the main trend is northwest-southeast, with high dips to the north-east. Limestone exposures are fairly widespread within the area, but appear to represent merely local bands and lenticles up to a few feet in thickness, within thick masses of schists. Occasionally thicker runs of limestone up to about 20 feet in width across the general strike are found. Some of the limestones are of good quality, but most are poor. No great mass of limestone appears to be present and development is unlikely.

Hosir (Hemandaytoli)-Bachra (Chargharwatoli)-Dundu-Ray (23° 40′ : 85° 03′—85° 07′), part in Ranchi and part in Hazaribagh district. Strike of the zone is east-west, and the width varies from 800-1,200 feet. Dips are steeply north. In the Hosir-Bachra section, at the east end of the zone, the limestone forms an east-west series of four hills rising 100-150 feet. Calcareous schists are interbedded, but the main mass is of good quality limestone suitable for cement manufacture. In the western or Dundu-Ray section of the zone, beds of calcareous schists become much more numerous. Here it is being developed by the National Cement Mines and

Industries Ltd., with three kilns for the manufacture of lime at Ray. Dolerite dykes cut the limestone.

Babhane-Hoyar-Khalari (23° 38′—23° 40′ : 85° 00′—85° 01′), Ranchi District. This zone of limestone can be traced, with few breaks in exposure, from Babhane to Khalari on a general east-west strike, and forms a prominent ridge in the Khalari area. At the eastern, or Babhane end of the zone, schists are considerably interbedded with the limestone. Westward, the limestone becomes more massive and at the extreme western end, at Khalari, there are practically unbroken exposures of good quality limestones (suitable for cement manufacture) across the strike for a width of 500-800 feet. The limestone beds dip steeply to the north and are overlain by a considerable thickness of highly calcareous schists along the general line of the E. I. Railway. The Khalari end of this limestone is being worked by the Dewarkhand Cement Co. (Associated Cement Co., Ltd.), and provides all the requirements of the cement works at Khalari.

Olhepat-Diridag (23° 49′ : 84° 43′—84° 44′), Palamau district. A complex series of highly calcareous gneisses and schists with impure granular crystalline limestones occur here. There is apparently no well-defined zone of good quality limestone. The outcrops occur in relatively flat areas of uncultivated and semi-cultivated ground.

Small deposits of magnesian limestone are known to occur in the Iron-ore Series in Singhbhum. Most of these have been recrystallised and are too impure to be of use. A relatively unaltered magnesian limestone occurs at Putada Springs, north of Chaibasa (22° 33′ : 85° 48′), an analysis of which is given on page 210. A limestone in fault breccia to the north of Lota Pahar station (22° 37′ ; 85° 34′) was quarried and calcined at one time, but is now abandoned. A dark bluish massive limestone occurs at Ghatkuri (22° 18′ : 85° 24′) and a more extensive bed, perhaps 300 feet thick, of magnesian limestone crops out across the Karo river, south of Patang (22° 23′ : 85° 24′). It is high in cherty silica.

In the Kolhan Series of Singhbhum, immediately overlying the basal sandstone, there is a zone of limestone an analysis of which is given in Table 26.

TABLE 26.—*Analysis of Kolhan limestone.*

	From Basakuti. Percent.		Average of 60 samples. Percent.
SiO_2	22·10	Insoluble	8·29
Al_2O_3	8·51	Al_2O_3 / Fe_2O_3	0·88
Fe_2O_3	0·39		
CaO	35·80	CaO	50·58
MgO	0·72	MgO	0·53
Na_2O	1·34	Loss on ignition	39·78
K_2O	0·32		
MnO	0·84		100·06
Loss on ignition	30·13		
Total	100·15		

Outcrops of this rock extend south from Chaibasa to Jagannathpur (22° 13′ : 85° 39′), a distance of about 30 miles. It is of variable thickness, thinning out completely in places, but perhaps it attains its greatest thickness, about 40 feet, near Rajanka (22° 26′ : 85° 44′) where it has been prospected by the Tata Iron and Steel Company. The material grades, with increase in impurities, to a phyllitic shale. Its structure is thin-bedded and flaggy, a structure which the Hos have found to be eminently suitable for its use as burial slabs.

VINDHYAN.

Perhaps the best limestones in Bihar are those of Vindhyan age in Shahabad district. These have been recently examined by Mr. J. B. Auden of the Geological Survey of India, who has supplied the following information concerning them.

The Rohtas limestone forms the topmost stage of the Semri Series, which belongs to the Vindhyan System. It crops out along the left bank of the Son river in the lower slopes of the Kaimur scarp from Rewa State through Mirzapur district into Shahabad district in Bihar. The length of the outcrop in Bihar, neglecting embayments in the scarp, is about 45 miles.

The limestone occurs immediately below the Lower Kaimur sandstone, the base of which forms a useful datum line in estimating thicknesses. The full sequence of the Rohtas limestone is not exposed in the area of Shahabad district visited by Auden, since alluvium covers up the underlying formations. In Mirzapur

district Auden estimates the maximum thickness to be about 700 feet. At Chunhattar (24° 36′ : 83° 52′) in Bihar, the minimum thickness is about 500 feet. Northeast of Chunhattar, on account of the gentle northward dip of the Vindhyan rocks, the Rohtas limestone becomes progressively overlapped and drowned by alluvium, until it finally disappears at Margohi (24° 52′ : 84° 04′) and only the overlying Kaimur rocks are exposed. The Rohtas limestone also occurs in patches along the north side of the Kaimur scarp, one outcrop being at Dumarkhar (24° 48′ : 83° 53′).

The Rohtas stage consists of alternations of fairly pure limestone with more impure limestone, calcareous shale and shale. The limestone bands are thicker towards the base of the stage, one bed between Baulia (24° 36′ : 83° 55′) and Banjari (24° 41′ : 83° 59′) averaging as much as 30 feet. Higher up, the proportion of shale to limestone increases and the individual beds become thinner, being seldom over 3 feet.

The limestone is extensively quarried for the manufacture of cement, quarries being common from Chunhattar in the west to Ramdhira-on-Son (24° 64′ : 84° 02′) in the east. It is also quarried at Dumarkhar. On account of the variable dips, and the disturbance of true dips by surface creep, it is not easy to determine the depth range at which the best limestones for the manufacture of cement occur below the Lower Kaimur sandstone. Between Baulia and Banjari the best limestones are approximately between 250 and 450 feet from the top of the Rohtas stage (and base of the Lower Kaimur sandstone). This horizon of good limestones is fully exposed between Chunhattar and Baulia, but gradually sinks below the alluvium towards the north, and is not exposed north of lat. 24° 47′ near Ramdhira-on-Son. The limestones towards the top of the Rohtas stage are also used in the manufacture of cement, but they are thinner and more variable in composition.

The limestone is termed 'fat' if possessing over 80 percent of calcium carbonate. The composition of the fat Rohtas limestones varies between the following approximate limits:—

	Percent.
$CaCO_3$	80 to 95
$MgCO_3$	2 to 3·5
SiO_2	3 to 12
R_2O_3	1·5 to 3

The composition of a good fat limestone is as follows:

	Percent.
$CaCO_3$	89·0
$MgCO_3$	2·0
SiO_2	6·5
Al_2O_3	1·2
Fe_2O_3	0·9
Alkalies	0·4
	100·0
S. R.	3·1

$$\text{S. R.} = \frac{SiO_2}{R_2O_3} = \frac{6{\cdot}5}{2{\cdot}1} = 3{\cdot}1$$

The silica percentage of limestones containing from 80 to 90 percent calcium carbonate averages about 6·7, and of limestones containing 90 to 95 percent calcium carbonate about 4·5. The percentage of ferric oxide in limestones containing over 90 percent of calcium carbonate averages about 0·45. Out of a total of 595 analyses of Rohtas limestone provided by the Sone Valley Portland Cement Co., there are 65 analyses (11 percent) in which the percentage of ferric oxide is 0·40 or under, and 9 analyses (1·5 percent) in which the percentage of ferric oxide is below 0·40. In Auden's opinion, it is likely that a few selected bands of limestone could be utilised in the manufacture of glass.

In the region of Baulia and Banjari from 40 to 50 percent of the quarry sections consist of fat limestone, and the remainder is rejected by the cement firms. The weighted average of calcium carbonate percentage of the fat limestones in one quarry west of Baulia is 86.

In the upper beds of the Rohtas stage the proportion of fat limestone diminishes to less than 30 percent, the remainder consisting of more siliceous and ferruginous limestones and calcareous shales. Some of this impure material is quarried at Dumarkhar where it is termed 'useful patra' and is mixed with the less common fat limestone. The difficulty of a satisfactory analytical control of these variable impure bands is evident.

At the top of the Rohtas stage in the vicinity of Banjari is found a band of hard dolomitic limestone containing 16·5 per cent. MgO (35 percent $MgCO_3$).

GONDWANAS.

Calcareous shales occur in the Talchirs near Daltonganj. It is possible that they could be used with good quality limestone for making cement, but they cannot be regarded as limestones.

Limestones occur within the lower Panchets near Baghmara (23° 39′ : 86° 45′), northwest of Panchet Hill, and were at one time

extracted in small quarries. The thickness varies up to 18 feet, the dips are E. 30°S. at 15°. Analyses are given in Table 27.

TABLE 27.—*Panchet limestone at Baghmara.*

	Percent.	Percent.
$CaCO_3$	63·40	45·05
$MgCO_3$	14·41	11·53
$FeCO_3$	4·15	3·64
Fe_2O_3	0·62	0·28
P_2O_5	0·12	0·07
Insoluble	19·28	39·28
TOTAL	101·98	99·85

This limestone was apparently used as a flux during the early days of iron-smelting at Kulti.

Future.

Although quite a number of limestone deposits have been opened up in Bihar, it cannot be said that resources are enormous outside of the Vindhyan deposits of Shahabad district. The Hazaribagh-Palamau deposits are, individually, not of unlimited extent, but will provide a very considerable industry down to the depth at which they can be economically worked. Quite extensive developments of the limestone industry may be expected both from Shahabad district and from the Damodar valley. Apart from the cement and lime-burning industries, the possibilities of manufacturing calcium carbide and calcium cyanamide in Bihar are well worthy of investigation.

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CHAPTER XXIV.

MANGANESE.

General.

Although manganese is one of the most important minerals produced in India, only a very small proportion comes from Bihar. The principal deposits in the province are in Singhbhum, from where there has been an intermittent production since 1906. Compared with the Central Provinces deposits those in Singhbhum are small, and individually they are soon exhausted. The greatest output has been during the last 10 years, but the Singhbhum deposits are likely to decline in output although other deposits are being opened up to the south, in Keonjhar and Bonai States. It is possible, however, that further deposits may be found in the future, in the thickly jungle-clad area of the Kolhan Estate, southwest Singhbhum. The annual production during recent years is given in Table 28.

TABLE 28.—*Production of manganese-ore.*

Years.	Bihar.		India.	
	Tons.	Rupees. (*b*)	Tons.	Rupees. (*b*)
1929	(*a*) 76,131	13,57,460	994,279	2,10,51,802
1930	(*a*) 48,724	7,63,641	829,946	1,62,03,186
1931	(*a*) 47,603	7,20,320	537,844	98,13,879
1932	(*a*) 47,180	3,40,427	212,604	18,62,293
1933	(*a*) 70,975	5,85,825	218,307	16,38,174
1934	15,112	2,51,237	406,306	51,63,592
1935	16,667	3,02,003	641,483	1,02,22,779
1936	11,722	2,31,912	813,442	1,49,54,812
1937	24,180	10,29,101	1,051,594	4,29,53,068
1938	24,469	9,86,387	992,795	4,00,51,488
1939	35,803	8,33,587	844,663	1,83,55,038

Exchange value taken as £1=13·4 Rupees.
(*a*) Includes production of Eastern States.
(*b*) Value f.o.b. at Indian Ports.

Uses.

There is a steady consumption of manganese-ore in India at the works of the iron and steel companies. Not only is it used in the

manufacture of ferromanganese but also it is added to the blast furnace in the manufacture of pig-iron and to the open-hearth furnace in the production of steel. As a rule, lower-grade ore is used in the blast furnace. Although the iron and steel works at Jamshedpur and near Asansol originally obtained their ore from the Central Provinces, ores from Singhbhum and Eastern States are now being used. Ferromanganese is manufactured by Tata Iron and Steel Co.; for this purpose it is desirable to utilise high-grade ore low in phosphorus.

Manganese-ores are also used in chemical industries as oxidising agents. Here, the manganese content of the ore is often not so important as the available oxygen, which is usually expressed in terms of the percentage of manganese peroxide, MnO_2. Impurities soluble in acid are deleterious, and, for the glass industry, the ore must be as free as possible from iron. Such ores usually contain over 80 percent MnO_2.

A particularly pure variety of chemical ore is used in the manufacture of dry cells; it is not quite clear what is the best type of ore for this purpose, as within limits the amount of MnO_2 in the ore does not appear to affect the suitability. Presumably the physical condition of the MnO_2—that is, the mineral constituents in which it occurs—is the important factor. High-grade manganese-ores whenever found should be tested for this purpose.

Grading.

Many iron-ores contain manganese, and indeed there is every gradation from iron-ores to manganese-ores. The following classification is adopted for such ores—

Manganese-ore—35 percent Mn and over.
Ferruginous manganese-ore—10 to 35 percent Mn.
Manganiferous iron-ore—5 to 10 percent Mn.

Normally, in India, manganese-ore is graded as follows—

First grade ore—over 48 percent Mn.
Second grade ore—between 45 and 48 percent Mn.
Third grade ore—below 45 percent Mn.

In Singhbhum, however, this grading is not used; all ore below 48 percent manganese is either sold as second grade, even down to 38 percent, or the ore is simply sold on its analysis. Chemical

ore, sold as "peroxide", may reach as high as 58-59 percent manganese. Some ores, down to 32 percent Mn, with as much as 17 percent iron, are sold as manganese iron-ores to the iron and steel industry.

Distribution.

The earliest manganese-ores produced in Singhbhum were obtained in 1906 from a small area extending to 6 miles south of Chaibasa, close to the following villages: Madkamhatu, Gitilpi, Kelendeh Tutugutu, Surjabasa and Bistampur. Since then other ores have been worked in the southern Kolhan, in the area between Noamundi and Gua. Deposits have also been recorded from Leda Buru (22° 28′ : 85° 23′), and from Lanji (22° 49′ : 85° 35′) in northern Singhbhum.

In 1927 the East India Manganese Company was floated with a capital of £110,000 to work supposed managanese deposits between Mirgitanr (22° 43′ : 86° 29′) and Basadera (22° 40′ : 86° 30′) in north-eastern Singhbhum. But the manganese occurs only as scattered debris, no workable deposits exist and the company was soon in liquidation. Any further attempt to work manganese here is foredoomed to failure. Other occurrences are recorded also at Jhatijharna (22° 42′ ; 86° 33′), Lahkaisini Pahar (22° 42′ : 86° 34′) and Hatibari (22° 36′ : 86° 39′), but, like the Basadera occurrence, are of no economic importance.

In Manbhum there has been some prospecting for ore near Paharpur (22° 58′ : 86° 15′) but the material is low grade; one analysis gave only 22·27 percent MnO, and the quantity available is small.

In Monghyr occurrences of no economic value have been recorded from the Katnowa hills (one analysis gave 28·26 percent Mn), and Pandipahari hills, but the latter locality has not been traced.

Mode of occurrence.

The manganese deposits of Singhbhum occur both in the Iron-ore Series and in the Kolhan Series.

The deposits close to Chaibasa occur in the basal part of the Kolhan Series, replacing both the basal sandstone and limestone. The ore occurs as thin lenticles parallel to the bedding of the rocks, or as lateritic material at the surface; the latter is commonly high in iron. All the ores are concretionary and the manganese has

been segregated by solutions which obtained their manganese content probably from underlying manganiferous rocks of the Iron-ore Series. They consist mainly of psilomelane and pyrolusite. Each of the analyses of ores from here, given in Table 29, represents the average of three analyses.

TABLE 29.—*Analyses of manganese-ore near Chaibasa.*

	Manganese-ore.	Manganiferous laterite.
	Percent.	Percent.
Mn	47·66	11·84
Fe	2·90	34·97
SiO_2	4·63	16·46
P	0·34	0·46
Moisture . . .	0·63	1·17

These ores near Chaibasa are practically worked out.

In the southern Kolhan and at Leda Buru, the ores occur in phyllites of the Iron-ore Series, but are in places associated with cherts. They occur in two ways: either as thin lenticles in phyllites or irregular masses in chert by replacement; and as manganiferous surface laterite. The occurrences are sometimes traced from the debris shed by them. The higher grade deposits are generally associated with chert. The largest deposits are probably of the surface lateritic type, which may be of quite high-grade ore. At one point near Gua, an outlier of basal Kolhan Series conglomerate contains a little manganese. Although most of the southern Singhbhum ores at present being worked are small others will probably be found from time to time.

At Basadera etc., in northeastern Singhbhum, and at Paharpur in Manbhum, the manganese all occurs in Iron-ore Series phyllites which stratigraphically belong to the same zone as the phyllites in southern Singhbhum.

The occurrence at Lanji in northern Singhbhum is of interest in that it is of a manganiferous laterite overlying lava, indicating that the lava is slightly manganiferous.

Future.

The manganese-mining industry in Bihar is unlikely to increase, indeed, the contrary must be expected. No workable deposits outside of Singhbhum have been discovered in the province, and

in the extensive tract of granitic rocks to the north, across central and northern Chota Nagpur, it is scarcely to be expected that new deposits will be found.

In Singhbhum, the deposits near Chaibasa are almost worked out. Further south in the Kolhan, the known small deposits are worked according to the market demand. In this dense jungle tract the discovery of other deposits is probable, but, from their very nature, none are likely to be of any size. It can never be an extensive industry.

In order to make the most of what manganese there is available, any new deposits should be tested for their usefulness to the chemical industry or in the manufacture of dry cells. Ores used for these purposes will have a greater value than if merely shipped for export or to iron and steel smelters. It should be not at all impossible to manufacture dry cells in the province.

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CHAPTER XXV.

MICA.

General.

The mica industry in Bihar is of great importance not only to the province but also to the world. From the mica belt, which extends for some 90 miles from the eastern side of Gaya district across Hazaribagh, into Monghyr and Bhagalpur districts, and with a width of up to 20 miles, comes over 80 percent of the world's supply of better quality sheet mica, and up to 80 percent of mica splittings used in the manufacture of micanite. The electrical industry is dependent on mica supplies from Bihar. In Table 30 the recorded production of mica during recent years is given, with the annual values, for comparison with the total value of mica produced in India.

TABLE 30.—*Production of mica.*

Years.	Bihar.		India.	
	Cwts.	Rupees.	Cwts.	Rupees.
1929	42,560	20,77,784	53,231	26,59,759
1930	40,887	19,92,204	52,727	26,68,986
1931	31,720	16,69,720	38,963	20,37,634
1932	24,097	10,35,466	32,713	14,35,401
1933	32,674	12,59,180	41,075	16,82,045
1934	45,979	16,86,266	55,706	20,76,599
1935	50,821	21,38,731	65,430	25,65,314
1936	71,738	27,00,147	99,143	32,92,826
1937	85,978	31,70,933	133,640	40,42,228
1938	84,235	34,12,315	160,144	43,42,267
1939	85,662	38,67,280	139,758	51,80,934

The greater part of Bihar's production has been shipped, in the past, to the United Kingdom, United States, Japan, and Germany for use mainly in electrical industry.

The mica industry has been in existence in Bihar for about 70 years, and, particularly since 1919, has expanded enormously. The recorded production in 1938, 84,235 cwts., is nearly two and a half times that of 1919, 34,230·2 cwts. Employing, as it does, a

total labour force of up to 150,000 people it is one of the largest and most valuable industries in the province.

The literature dealing with the Bihar mica belt is fairly extensive, but the aspect of the industry has changed so rapidly in the last few years that previous accounts no longer give a reliable present-day picture of the state of the industry. This is particularly true of the mining technique now applied on the belt.

Uses.

Mica is the name applied to a group of complex alumina-silicates of potash, iron, magnesia, etc. The mica mined in Bihar is the potash mica known as muscovite. Its most striking property is the ease with which it can be split along the cleavage planes into extremely thin films. It is also transparent and colourless in thin sheets, resilient and tough, chemically very stable, resistant to high temperature and a nonconductor of heat and electricity.

Its remarkable insulating properties make mica invaluable to the electric industry. It is used for commutator insulation, armature insulation, transformers, electric heaters, rheostats, condensers, radio tubes, fuse boxes, lamp sockets, sparking plugs, and as washers, etc. Small thin films or splittings cemented together are built up into sheets and sold as *micanite*. The larger sizes of mica are also used for stove and furnace windows, gas lamp chimneys and shades, etc.

Ground mica, made from waste, is used in the manufature of patent roofing, wall paper, automobile tyres, moulded insulators, as a filler in rubber goods, etc., and for fancy paints and lubrication.

Marketing.

The mica mined in Bihar is of various colours, green, brown white, silver and ruby. The most valuable is that known as " ruby mica " to which class most of the production in the Bihar mica belt belongs. Sheets of this mica, even about ⅛-inch in thickness, have a beautiful ruby colour, the depth of which increases with thickness.

After the crude mica from the mines has been cut and flaws removed, it is known as " block mica ", the thickness of which may vary down to ·008 inch. The percentage of block mica produced from crude mica is probably between 20 and 25 percent for the belt as a whole.

Block mica is sorted according to size and quality. Defects consist of cracks, stains, interlaminar and other inclusions, air inclusions and warping. Sometimes such defects can be eliminated by further splitting and cutting, thus improving the quality of the final block, but there is obviously an economic limit beyond which it is inadvisable for this to be done. For use in condenser plates, the mica must be very level, free from warping, stains, etc.

The various qualities are described as follows:

Superfine.	Stained.
Clear.	Heavy stained.
Slightly stained.	Badly stained.
Fair stained.	Densely stained.
Good stained.	Black spotted.

These qualities are, unfortunately, not standardised. Different sorters and firms have their own interpretation of individual quality and, in addition, selling competition gives rise to variation. With a view to removing these difficulties the Geological Servey of India has new made available curefully prepared standards at Rs. 50 per set. On the whole, however, there is an approximately consistent local standard which might be referred to as the "bazar market standard".

If, on this bazar market standard, fair stained and better mica is regarded as "high quality", the rest being regarded as "low quality", then the proportion of high to low quality mica produced in the Bihar mica belt is approximately 1 to 10.

The following grading according to sizes is used:

Over Ex. Ex. Special	100 and over square inches.
Ex. Ex. Special	80-100 ,, ,,
Extra Special	64-80 ,, ,,
Special	48-64 ,, ,,
A-1	36-48 ,, ,,
No. 1	24-36 ,, ,,
,, 2	15-24 ,, ,,
,, 3	10-15 ,, ,,
,, 4	6-10 ,, ,,
,, 5	3-6 ,, ,,
,, 5½	2½-3 ,, ,,
,, 6	1-2½ ,, ,,
,, 7	Below 1 ,, ,,

Of these sizes, perhaps 15-17 percent, of the production of dressed mica is represented by sizes No. 4 and up, the remainder is of the smaller sizes.

The greater part of all sizes of high quality mica is exported as block mica. Of the low quality mica the greater part of all sizes No. 4 and up is exported as block mica, but sizes Nos. 5 and down are almost entirely split into extremely thin films which are known as "splittings" (approximately ·001 inch in thickness). However, a certain fraction of these small sizes, depending on the market requirement, is exported as block. From the high quality block mica a steadily increasing amount is being made into condenser splittings in India.

At a very rough estimate the following are the approximate percentages of the dressed mica produced in Bihar from mines which keep records:

	Percent.
High quality block mica, all sizes	9
Low quality block mica, No. 4 and up	14
Low quality block mica, No. 5 and down	6
Splittings (derived from No. 5 and down)	71
TOTAL	100

It must be understood that for any one year these percentages will vary either way. In addition there is a considerable amount of unre orded mica exported, and also many of the old dumps have been turned over in recent years for mica from which splittings are made. The reported mica is divided into approximately 80 percent splittings and 20 percent block.

The prices obtained depend on quality and size, and for each grade the price will vary widely from time to time according to the demand. For extra special sizes, superfine, prices as high as Rs. 100 per lb. are obtained, but the total quantity of such mica produced per year amounts to only a few maunds. Small sizes, stained, may sell at less than Re. 1 per lb. The industry depends for its stability rather on the large production of low quality mica of all sizes. For block mica the average price per cwt. has varied from Rs. 171 to Rs. 233 between 1934 and 1938. For splittings the average price has varied from Rs. 47 to Rs. 89 in the same period. For all mica, block and splittings, the average price per cwt. has varied from Rs. 74 to Rs. 120 between 1934 and 1938.

Several of the bigger producers of mica in Bihar are also dealers, purchasing from the smaller producers in the local market. The

bigger shippers have their own agents in London and New York, where stocks are kept. Although a large proportion of shipments is against direct orders from producer to consumer, a considerable amount of business is done through brokers.

Distribution.

Although the whole of the production of mica in Bihar now comes from the Bihar mica belt, extending from Gaya district on the west across Hazaribagh and Monghyr districts into Bhagalpur district on the east, mica has also been obtained in the past from other areas.

To the south of the belt, a small mica-bearing area has been recorded near Dhengura (23° 57′ : 85° 20′), 4 miles southwest of Hazaribagh.

In Singhbhum, a pale green mica has been prospected at Puranadihi (22° 20′ : 86° 39′), Benagaria (22° 19′ : 86° 38′) and Laubera (22° 32′ : 86° 41′).

In Manbhum, the mineral has been worked recently at Chitra (23° 32′ : 86° 26′), Kanki (23° 35′ : 86° 29′) and Sonkupi (23° 08′ : 86° 04′). It has also been recorded at Ghatbera (23° 11′ : 86° 13′), Marlong (23° 27′ : 86° 01′), Taherbera (23° 28′ : 86° 02′), Jabar (23° 27′ : 86° 01′), Maramo (23° 28′ : 86° 02′), Simni (23° 27′ : 86° 00′), Bhursa (23° 09′ : 86° 40′), Rangadih (23° 01′ : 85° 53′), Churku (22° 49′ : 86° 36′), Jhairbaid (22° 50′ : 86° 36′), Jashpur (22° 48′ : 86° 36′) and between Urma (23° 43′ : 86° 42′) and Chirudih (23° 43′ : 86° 37′).

In Palamau it has been recorded from near Daltonganj (24° 02′ : 84° 04′), Lesliganj (24° 02′ : 84° 12′), Kini (24° 04′ : 84° 01′), and Khorhi (24° 02′ : 84° 00′). Mica has also been recorded from Sikriadanr (22° 41′ : 84° 29′) near Simdega, Ranchi district.

The mica, throughout, occurs in pegmatite within schists close to granite, but in all of the above places outside of the mica belt it is either small in size or badly stained.

Within the mica belt, the greatest production has come from the Kodarma Reserved Forest, north of Kodarma, perhaps one-third of the total production from Bihar, but an increasingly large amount is now being obtained elsewhere, particularly from northeast of the Reserved Forest, from further east near Gawan, and from northeast of Parsabad station. The western end of the belt, west of the Reserved Forest, in Gaya district, has been gradually decreasing in activity. During recent years production

from the Reserved Forest has been 2 to $2\frac{1}{2}$ cwts. of dressed mica per acre of the area leased. In more normal times it would be a little below 2 cwts. Apart from the Reserved Forest, the whole of the remainder of the mica belt is held by zamindars who either mine mica themselves or have leased or sold outright the mineral rights to the miners. On the whole, deposits outside of the Kodarma Reserved Forest are more widely scattered than those within the Forest area, and the quality of the mica is not so good.

The notes which follow relate entirely to the mica belt.

Mode of occurrence.

A detailed survey of the Bihar mica belt is now being made; hitherto no detailed geological map of the belt has been available.

The mica occurs as a constituent of veins and masses of pegmatite which penetrate mica-schists. The veins commonly strike and dip parallel with the cleavage of the enclosing schists. These pegmatites consist normally of plagioclase felspar and quartz, but also in places contain orthoclase felspar and such minerals as tourmaline, garnet, apatite and very rarely beryl. The mica occurs as "books" within the pegmatite; these books may vary up to as much as 3 feet or more across, but the average is perhaps 6-12 inches. The thickness of the books may also vary up to 2 or more feet, but the average is probably less than 3 or 4 inches.

The mica occurs more commonly towards the sides of the veins, rather than in the centre; sometimes it is found in the schists immediately adjacent to the veins, or in inclusions of schists within the veins.

On a very broad approximation for veins which produce mica, 1 maund of crude mica is obtained from 8 cubic feet of vein material excavated. Of cut block mica, this represents about 1-1·5 percent of vein material.

The veins vary in thickness from a fraction of an inch to over 100 feet. The thicker veins almost invariably have a core of quartz, the felspar and mica being arranged on either side of this core. Occasional veins are entirely of felspar with some mica, in others the mica occurs in a simple quartz vein carrying no felspar.

The mica zone in any vein does not as a rule exceed 3 feet in thickness. These zones occur in "shoots" of variable length along the vein, and pitch either steeply or vertically downwards in the plane of the vein.

The pegmatites may carry payable mica for any distance along the strike up to perhaps 1,000 feet. The great majority of the veins are short, not even 100 feet in length. Some of them are almost pipe-shaped, but may extend down to several hundred feet. Usually a vein still continues in strike and depth even though it has become unpayable.

So far as the recent survey of the mica belt has gone it has become clear that payable mica-bearing pegmatites never occur within granite, but only within mica-schists which appear, however, to be rather variable in composition and are in places gneissic.

The question has sometimes been asked, to what depth will the mica pegmatites be found? Individual veins are obviously lenticular, and just as they thin out along the strike, so also they thin out in depth. Veins have been worked to a depth of 500 feet. But because any individual vein may thin out at this depth, there is no reason why adjacent veins, which may not have reached the surface, should not continue to a much greater depth. These mica pegmatites bear no relation to the present land surface, but were formed at a high temperature below a great thickness of the earth's crust which has been since removed, and were formed within a considerable depth range of the crust. The present vertical range over which they are known to occur is between the level of the plateau at Kodarma, 1,250 feet, and the lowest depth of one of the mines along the rivers debouching on to the Gangetic plains—a total range of at least 1,000 feet.

Mining.

Probably 25 percent of the mica of the Bihar belt is produced from surface workings, known as "uparchalla" workings. The remainder is produced from mines extending to variable depths, down to 500 feet from the surface. In recent years, some 150-200 underground mines have been working under the Mines Act.

Until about 1918 most of the mica was produced from uparchalla or quite shallow mines, which were rarely worked systematically. Many of the mines were open cuts, others were little better than rabbit warrens, tortuous holes and tunnels which followed the mica from book to book. Machinery was rarely used, and a mine was abandoned when it became impossible to deal by baling with the water which entered the mine.

Gradually, however, the technique of mining on the belt has improved, and most of the larger firms are now working in a systematic and sound manner. All of the larger mines have become mechanised, costs have been reduced, and mines are being constantly reopened which had been long abandoned. There is, however, still room for improvement on the part of some of the smaller mine owners.

The normal method of working is for the vein to be opened up or "developed" to its limits in depth and strike by shafts, drives and winzes. The vein is in this way blocked out, leaving considerable reserves in the blocks between drives and winzes. The size of the blocks depends on the distance between drives, in some cases this is only 10 feet, but in better-class mining it is 30 and even 50 feet. After the vein has been thoroughly explored to its limits, the reserves are removed by "stoping", until the mine is completely worked out. In some mines a certain amount of stoping is carried out whilst development is in progress.

Future.

Mica mining in Bihar has a lengthy future ahead of it, so long as no return is permitted to the old wasteful methods of mining. Invaluable records of abandoned mines have been lost, or unsystematic uparchalla work has obscured the evidence of the existence of many veins. But from a survey of the belt it is evident that there are immense reserves still to be opened up.

So long as indiscriminate uparchalla or shallow surface work is permitted, or is possible, mica mining can be undertaken with little or no capital. Because of the harm that it does in obliterating surface evidence it would be advisable to stop all uparchalla mining of an indiscriminate nature in which no records are kept.

Mica mining is now being undertaken at progressively greater depths, and this requires an increasing amount of capital. The time has come in Bihar for it to be clearly understood that it is an industry for larger concerns with capital and not for the small man or individual villager. Unless this is appreciated, and wasteful surface methods stopped, the life of the mica belt could be very easily curtailed at an early date. But worked soundly, by companies with plenty of capital and staffed by trained technicians, and with Government administration favourably disposed towards conservation of its mineral resources, the life of the belt will be indefinitely prolonged.

At present, mining is in progress on such veins as crop out at the surface. New mines opened up to-day are usually on old shallow workings which had been abandoned at water level or for other reasons. There are still many of these to be reopened. Underground exploration from one vein sometimes leads to another thus indefinitely prolonging the life of a mine. Until recently, no geological mapping underground had been done, but this would be of inestimable value in determining the extensions of veins. There has been no sign of any exhaustion of the belt as yet, indeed production has progressively increased and there is every indication that it will continue to increase. Eventually, in the somewhat distant future, it will become necessary to explore at depth for veins which do not crop out at the surface, but geology will undoubtedly find a means of tackling that problem. At present there is little or no difficulty in locating pegmatite veins, but only a small proportion of these contain payable mica. When the geological survey has resulted in a more thorough knowledge of the mica belt, after some years, it may be possible to guide mining in the location of mica-bearing pegmatites at depth. Ultimately, perhaps, some improved form of geophysical prospecting may be utilised, but the author would not recommend any of the existing methods, particularly until the geology is more thoroughly understood.

Perhaps the basis of the Bihar mica trade to-day is the ability to produce splittings cheaply. No doubt production could be increased in other countries if the mica could be split efficiently and cheaply, permitting those countries to compete with India. This must be always remembered, and, although there is scope for a greater income from the mica trade both to Government and to the mica labour, the industry should never be so unduly burdened as to inhibit its ability to hold its premier position in the world's mica trade.

In recent years the greatest impetus given to mica mining in Bihar was the introduction of the Bihar and Orissa Mica Act of 1932. Mica thieving had been so rife that, in 1927, the Government of Bihar and Orissa, in consultation with the Director of the Geological Survey of India and the Chief Inspector of Mines, framed certain rules which aimed at restricting illicit trade in mica. These measures, on being placed before the provincial Legislative Assembly were rejected, but, after subsequent amendment, became law in 1932. This reduced illicit dealing to a negligible amount and

bonâ fide miners and dealers were able to obtain the full benefit of their operations. In February 1939, however, the Mica Act was repealed, and immediately hundreds of small dealers sprang up throughout the belt. There was no control of the movement of mica, and mica thieving again became rife. A year later the Mica Control Order was instituted to take the place of the repealed Mica Act. It is to be hoped that some control of this nature will remain permanently as otherwise illicit practices may recommence and eventually cause a serious curtailment of mining operations on the part of sounder companies, from which the trade may find it very difficult to recover.

It must always be remembered that the world's electrical industry in its present form, is dependent on mica from Bihar. The province should regard itself as the world's trustee for this mineral and conserve it with the greatest care.

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CHAPTER XXVI.

MINERAL FERTILISERS.

General.

Mineral fertilisers, to an agricultural country like India, are becoming of greater importance as cultivation of the soil becomes increasingly intensified. The country's resources in natural fertilisers are not great and it is essential, therefore, that the best use should be made of whatever materials are available.

Fertilisers are of various types, according to whether they provide the soil with nitrogen, potash, phosphorus, calcium or other elements. In Bihar, a supply of most of the more important fertilisers is available, and in this respect the province is perhaps more happily placed than is any other province in India.

Nitrogen.

The main fertilisers used as a source of nitrogen are: nitrate of soda, nitrate of potash, sulphate of ammonia, calcium cyanamide. No nitrate of soda is produced in Bihar, or indeed in India, but there are means of developing the production of the other salts.

Nitrate of potash.—The occurrenee of saltpetre in northern Bihar is described in Chapter VIII. Part of the crude nitrate-bearing earth (*lona-mati*) is used directly as fertiliser, although most is treated for the extraction of saltpetre. Some of the extracted crude saltpetre is also used as fertiliser.

Sulphate of ammonia.—One of the by-products in the distillation of coal to form coke is ammonia which is recovered as a sulphate. Most of the coking plants in Bihar are also recovering ammonium sulphate, the principal producers being:

Tata Iron and Steel Co., Ltd.
Bararee Coke Co., Ltd.
Burrakur Coal Co., Ltd.
Londa Colliery Co. (1920), Ltd.
East Indian Railway Colliery, Giridih.
Eastern Coal Co., Ltd.

The annual production of ammonium sulphate during recent years is given in Table 31. The average ammonia content of this material is about 25 percent ammonia.

TABLE 31.—*Production of sulphate of ammonia.*

	BIHAR.	INDIA.
	Tons.	Tons.
1929 . . .	10,637	17,567
1930 . . .	10,103	16,131
1931 . . .	9,128	12,133
1932 . . .	7,203	9,474
1933 . . .	7,713	9,885
1934 . . .	8,567	11,775
1935 . . .	9,299	15,398
1936 . . .	8,597	17,603
1937 . . .	9,477	18,150
1938 . . .	10,809	14,616
1939 . . .	17,413	24,192

Consumption of ammonium sulphate as a fertiliser in India is gradually increasing. Considerable quantities are imported each year and there is room for an increase in domestic production.

Ammonia may also be produced synthetically by the Haber-Bosch process, from incandescent coke, air and steam. The ammonia is dissolved in water and combined with carbon dioxide also produced in the process. The ammonium carbonate, in solution, is then treated with calcium sulphate (gypsum) with the formation of calcium carbonate and ammonium sulphate. The calcium carbonate may also be used as a fertiliser or used in the manufacture of cement. No plant using this process is at work in Bihar, but the economic possibilities of such an industry, utilising gypsum from the Salt Range, might be investigated.

Calcium cyanamide.—At present the manufacture of calcium cyanamide has not been attempted in Bihar. This material is becoming increasingly important as a nitrogenous manure and a local supply would probably create a demand. The limestone from which it can be manufactured is available in the province.

Potash.

There are several sources of potash available: nitrate of potash, potassium sulphate and chloride, potash felspar, blast furnace dust, and cement kiln gases. Of these, the sources of nitrate of potash available in Bihar have been discussed above under Nitrogen, the material providing both nitrogen and potash to the soil. Potassium sulphate and chloride are not available in Bihar,

Potash felspar.—The pegmatites of the Bihar mica belt contain a certain amount of potash felspar. Pascoe (p. 21) has suggested that the mineral could be picked from the mine dumps, and crushed for use as a fertiliser. It is very doubtful whether this suggestion would be either practicable or economical.

The whole of this area is swarming with pegmatites dykes which consist usually of quartz and soda felspar, with variable amounts of potash felspar. It is probable that some of the veins, particularly those in the granite adjacent to the mica belt, may consist almost entirely of potash felspar; if the veins are of sufficient size, they could be used as a source of potash felspar also for the ceramic industry. Potash felspar pegmatites are occasionally found in other parts of Chota Nagpur associated with the granitic rocks, but they are usually high in quartz. To the north of Jainti (22° 04′ : 85° 41′), in south Singhbhum, some quite large pegmatites consist almost entirely of potash felspar.

Blast furnace dust.—The dust deposited in stoves and boilers and at the base of the chimney from iron-smelting blast furnaces is usually high in potash. This dust may contain up to 20-25 percent potassium chloride, 15 percent potassium hydrogen carbonate, and 5 percent potassium cyanide. By adding common salt to the blast furnace charge, sufficient chlorine may be provided to combine with all the potash, thus considerably increasing the yield in the flue dust. In Bihar, however, investigations so far made on the blast furnace flue dusts have not been encouraging. Their potash content is stated to be low, but the matter appears to be worthy of further investigation.

Cement-kiln gases.—Flue dust from cement-kilns also contains potash, which can also be increased by adding common salt to the kiln charge. In cement manufacture the collection of potash would require the erection of additional plant which would be costly, and it is probably for this reason that no attempt has yet been made in India to obtain potash as a by-product in the manufacture of cement.

Phosphate.

The principal sources of phosphate for the manufacture of fertilisers are: rock phosphate, apatite, bones, and basic slag from the smelting of basic steel. Of these, rock phosphate does not occur in India.

Apatite.—The deposits of apatite in Bihar have been described in Chapter IX.

Bones.—There is a very considerable export from India of bones and bone-meal, in which phosphates are an important constituent. The treatment of these, in the country, with sulphuric acid to form super-phosphate for fertiliser purposes will undoubtedly receive increased attention in the future.

Basic slag.—The slag formed during the manufacture of basic steel usually contains sufficient phosphate to make the ground slag useful as a fertiliser, but apparently Indian basic slags are rather deficient in phosphate. For every ton of basic steel manufactured by Tata Iron and Steel Company at Jamshedpur, about 250·300 lbs. of basic slag is produced, averaging 3 percent P_2O_5 in open hearth slag and 6 percent P_2O_5 in Duplex slag. This is piled on the dump heaps as there is no demand. During recent years the tonnages given in Table 32 were dumped

TABLE 32.—*Basic slag dumped at Jamshedpur.*

	Tons.
1929	49,625
1930	38,875
1931	31,575
1932	24,000
1933	24,750
1934	89,254
1935	97,539
1936	97,043
1937	99,434
1938	105,166

Miscellaneous fertilisers.

Gypsum.—The value of gypsum for the monsoon crops of South Bihar has been experimentally demonstrated by Clouston (Pascoe, p. 52). There are, however, no deposits of gypsum in Bihar and supplies have been imported from Bikanir.

Limestone.—Under certain conditions lime is beneficial to the soil, especially when accompanied by other fertilisers such as potash. There is, of course, no dearth of good quality limestone in Bihar.

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CHAPTER—XXVII.

MINERAL PIGMENTS.

General.

Three classes of mineral colours are in commercial use : (1) Natural mineral pigments, (2) pigments derived by direct treatment of minerals such as sulphides, and (3) chemically manufactured inorganic pigments. The natural mineral pigments include yellow ochre which usually consists of a clay base permeated by hydrated ferric oxide ; red ochre consisting of a clay base with red ferric oxide ; red oxide which is soft ferric oxide with little or no clay base ; umber and sienna which are brown earth colours, containing small amounts of manganese oxide. In addition, ground slate and shale are sometimes used as grey pigments.

There is a well-established industry in India for the preparation of colour earths and considerable quantities of oxides and ochres are supplied. At one time India exported large quantities of high quality yellow ochres, but the quality depreciated and the exports ceased.

Occurrences of red and yellow ochres are widely scattered in India and particularly in Bihar, but for the most part they are of inferior quality. Even the poorer ochres find a considerable use locally, for the colour washing of village huts, houses and temples, and for various other purposes.

Grades and quality.

The natural colour pigments may be divided into the red and yellow ochres, the red, brown, purple and black oxides, the siennas, and the umbers. The valuation of these requires expert judgment and is dependent upon the richness of colour, staining power and, in the case of the ochres and oxides, upon the iron content.

A simple test of these pigments may be made as follows: A sample is dried and finely powdered, then mixed with oil and spread over a piece of clear glass. The colour as observed through the glass is then compared with prepared samples of standard colours.

Before marketing, most ochres have to be dried, ground and sieved. In some cases, where mixed with coarse impurities, levigation is necessary. Sometimes the colour may be improved by calcining.

Uses.

The ochres of various shades have a reasonably good covering power, are permanent colours and have no effect on other pigments. They are extensively used in the manufacture of paint, oilcloth and linoleum, paper, and as a pigment in ceramics, cement, rubber goods, etc.

The oxide pigments are durable, good driers, possess good spreading power, and are cheap and inert. They are widely used for painting exposed iron and steel work, such as ships, bridges, railway trucks, and, like the ochres, are used as a pigment in linoleum, wall paper, cement and rubber goods. "Rouge", a finely ground form of pure oxide, is used for polishing metals, gems, etc.

A variety of ferric oxide, known as micaceous hematite, consists of natural minute thin scales of hematite which, after sifting and mixing with boiled linseed oil, is used for painting exposed iron, steel, and wood work.

The brown earths, the siennas and umbers, vary in colour from brown to reddish brown and comprise a wide variety of tints. They are largely used in printing, as artist's colours, and as a stain and colour filler usually with other colours.

Distribution.

Both red and yellow ochres are found in Bihar mainly associated with the basic igneous rocks and phyllites of the Archeans, and with the laterites.

Gaya.—Sherwill recorded that an indurated reddle of orange, purple, light red or yellow colours was formerly quarried on a small hill west of Gaya and used for dyeing cloths.

Manbhum.—In the hills along the edge of the Dalma lavas to the southeast and west of Chandil (22° 57′ : 86° 04′) there are deposits of red ochres and black carbonaceous phyllites similar to those in Ranchi district to the west. A clay at Rajabasa (22° 49′ : 86° 24′) is used locally as a colour wash.

Ranchi district.—A fine purplish red clay is sometimes found along the edge of the Dalma lava flows. This clay is apparently derived both from tuffs and from the lavas themselves. Quite a large amount of this material occurs on the ridges to be southwest of Kubasa (22° 57′ : 85° 48′) where the ochre is usually homogeneous but is occasionally finely banded—its inaccessibility appears to be its main drawback.

Attempts have been made to work red ochres in phyllites, just south of Ray station (23° 41′ : 85° 04′), but the quality is too poor.

Deposits of lithomarge which might be suitable as yellow ochres occur below the laterites on the small plateaux of western Ranchi.

Close to the Dalma lavas there are fine deep black carbonaceous phyllites which are soft and would be easily powdered, and might be suitable as a black pigment. The principal localities are Papirda (22° 57′ : 85° 39′) in Ranchi, and a belt between Kudda (22° 57′ : 85° 50′) in Ranchi and Gangokocha (22° 54′ : 85° 59′) in Manbhum.

Santal Parganas.—Ochres are known to occur in association with the clay deposits of the Rajmahal hills.

Shahabad.—Sherwill recorded that extensive beds of ochre were exposed on the Kaimur plateau at Madpa (24° 38′ : 83° 30′) and Chathans (24° 38′ : 83° 40′), and that the material was formerly carried to Patna and Benares for use in dyeing and as a pigment.

Singhbhum.—Red and yellow ochres of fair quality are found as pockets in the Iron-ore Series phyllites in the neighbourhood of Goilkera (22° 31′ : 85° 23′). Some two miles south of Kuira (22° 32′ : 85° 31′) massive shales grade to fine red ochres over quite a wide area. There are many similar occurrences in southern Kolhan, but the majority are not of high quality. However, the red clays which form the alteration product of lavas just below the base of the Kolhan Series may be of quite good quality in some cases. The villagers in Dhalbhum obtain ochre for colouring their huts from the ferruginous phyllites near Mangru (22° 29′ : 86° 16′) and north of Mahespur (22° 23′ : 86° 30′). Clays at Metiabandi (22° 33′ : 86° 38′), Kharhi dungri (22° 32′ : 86° 45′), and near Dharadih (22° 43′ : 86° 32′) are used as a colour wash.

In the Porahat, on Bicha Buru (22° 39′ : 85° 24′), Karamta Buru (22° 40′ : 85° 25′) and Lukud Buru (22° 40′ : 85° 27′) there are considerable deposits of micaceous hematite which have never yet received serious attention.

In southern Kolhan there are deposits of manganese-ores and it is possible that brown earths may be found associated with these and which might be used as siennas or umbers. Other possible localities are Leda Buru (22° 28′ : 85° 22′) and Basadera (22° 40′ : 86° 30′).

Future.

In view of the large imports of mineral paints into India, there does appear to be considerable scope for expansion of the local industry. Admittedly a large proportion of the deposits of ochre scattered throughout the province are of poor quality, but it cannot be taken for granted that additional deposits of suitable material will not be found. In particular, the deposits associated with the Dalma lavas and with the lavas and tuffs of the iron-ore area of southern Singhbhum, should repay a closer investigation. Also the micaceous hematites of the Porahat may later find a wide market. The use of the black carbon phyllites of South Ranchi and South Manbhum may prove a profitable source of black pigment.

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CHAPTER XXVIII.

MINERAL WATERS.

General.

Mineral springs, many of them possessing medicinal and radioactive properties, are quite numerous in many parts of India, and, in this respect, Bihar is perhaps the most abundantly endowed province. With the exception of a few springs, such as Sita Khund and Phillip's Khund in Monghyr district, and Vishwamitra and Makhdum Khund in Patna district, the waters from these springs have not as yet been exploited either for medicinal use or as table waters, notwithstanding that the curative value of some of these waters for certain diseases has long been recognised locally. However, some of these springs are held sacred, temples have been erected close by, and baths built in which pilgrims, who come from great distances, may bathe in the waters.

Recently, an investigation of the radioactive and medicinal properties of these springs in India has been commenced, and much of the information which follows, on the properties of some of the Bihar mineral waters, has been provided by Dr. P. K. Ghosh, of the Geological Survey of India.

Classification.

Dr. Ghosh classifies the spring waters into (*a*) Radioactive waters and (*b*) Medicinal waters.

The radioactivity of spring waters is given in terms of the amount of radon (emanation of radium) per litre of water. Several of the springs in Bihar compare favourably with some of the most radioactive waters overseas, used solely for their radioactive properties in curing all forms of rheumatic and arthritic conditions and for anæmia.

The medicinal value of the waters is judged by the amount of salts of medicinal value present in the waters, as compared with those present in recognised medicinal waters overseas. Various types of waters may be recognised in India:

1. (*a*) Sulphur waters (cold), Trinkquelle type.
   (*b*) Sulphur waters (warm), Aix-les-Bains type.

2. (*a*) High carbonate waters, Apollinaris type.
   (*b*) Lower carbonate waters, Evian water type.
3. Chloride (saline) waters, Marienquelle and Leamington type.
4. Chloride waters (milder).
5. Waters which do not resemble known European waters.

Up to the present, in Bihar, waters of the Aix-les-Bains type have been found as well as others having no resemblance to the usual European types.

In determining the medicinal value of a water the principal constituents analysed are: silica (Si), iron (Fe), aluminium (Al), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), carbonate (CO_3), bicarbonate (HCO_3), sulphate (SO_4), nitrate (NO_3), sulphide (S), chloride (Cl), fluoride (F).

The amounts of these constituents are determined in parts per million. In addition H_2S and CO_2 are found in many of the waters, whilst spectroscopic analysis has shown the presence, in some of the waters, of minute quantities of manganese, lithium, strontium, barium, copper, tin, zinc, lead, bismuth, boron, beryllium, titanium, molybdenum, palladium, ruthenium, osmium, iridium, platinum, gold, silver.

Distribution.

The springs occurring in Bihar are grouped mainly into the following areas, although occasional mineral springs are found in other parts of the province:

1. Rajghir Hills.
2. Hazaribagh.
3. Monghyr.
4. Santal Parganas.
5. Coalfields.

Only springs within the first three of these groups have recently been subjected to close investigation of their properties, others it is hoped will be examined in the future.

1. *Rajghir Hills.*—Springs are found at three distinct localities:

(*a*) The Rajghir springs (25° 01′ : 85° 25′), in Patna district, comprising more than a dozen springs.

(*b*) Tapoban (24° 55′ : 85° 19′), about 12 miles W. S. W. of Rajghir, in Gaya district, and totalling four springs.

(*c*) Agni Khund (25° 00′ : 85° 30′), 8 miles E. S. E. of Rajghir, in Gaya district, at the foot of a ridge, and comprising several minor springs in addition to the main spring.

All of these springs are associated with Archean quartzites.

2. *Hazaribagh.*—Springs are found in at least six localities:

(*a*) Suraj Khund (24° 09′ : 85° 38′), near Barkatta.
(*b*) Kawa Gandhawani (23° 44′ : 85° 23′), near Kanki, west of Mandu on the Hazaribagh-Ranchi road.
(*c*) Duari (24° 08′ : 85° 09′), on the western bank of the Balbal near Duari.
(*d*) Katkamsandi (24° 07′ : 85° 12′).
(*e*) Kesodih (24° 12′ : 86° 02′).
(*f*) Indra Jurba (23° 50′ : 85° 27′).

La Touche also recorded springs at Lurgurtha and Sosonia but these places cannot now be located.

At Suraj Khund there are six springs, in pegmatite and aplitic granite with silicified quartzite. At Kawa Gandhawani there are four minor springs in addition to the main spring, and all are in granite-gneiss. At Duari, four springs emerge from the soil, with crushed chalcedonic quartzite, probably fault-rock, in the vicinity.

3. *Monghyr.*—Springs have been recorded from at least nine localities in the vicinity of the Kharagpur hills. In the following list only those at the first two localities have been the subject of recent investigation:

(*a*) Sita Khund (25° 22′ : 86° 32′).
(*b*) Rishi Khund (25° 15′ : 86° 32′).
(*c*) Bhimabandh (25° 04′ : 86° 24′).
(*d*) Bhurka (? 25° 18′ : 86° 37′).
(*e*) Janam Khund (25° 07′ : 86° 24′).
(*f*) Lachmi Khund (? 25° 03′ : 86° 29′).
(*g*) Panchbhur (25° 06′ : 86° 15′).
(*h*) Rameswar Khund (? 25° 09′ : 86° 30′).
(*i*) Singhi Rikh Tatal Pani (25° 08′ : 86° 18′).

At Sita Khund there are two main springs, Sita Khund and Phillip's Khund. They occur in the soil-covered plain in which the underlying rock is apparently a much jointed and fractured quartz. At Rishi Khund nineteen springs were examined at the foot of the quartzite ridge.

4. *Santal Parganas.*—Most of the springs in the Santal Parganas lie to the west of the Rajmahal hills, but two occur within the Rajmahal traps. A total of seven springs has been recorded:

(*a*) Bhumka (24° 02′ : 87° 17′).
(*b*) Nunbhil (24° 05′ : 87° 13′).
(*c*) Susumpani (24° 09′ : 87° 17′).
(*d*) ?Tapatpani (24° 12′ : 87° 21′).
(*e*) Jharia (24° 20′ : 87° 42′).
(*f*) Baramasia (24° 31′ : 87° 39′).
(*g*) Lau-lau-dah (24° 22′ : 87° 43′).

La Touche recorded a spring at Tatloi but it has not been possible to trace this locality recently.

The Bhumka and Jharia springs are in marshy ground. At Nunbhil, Susumpani, and Tapatpani, the springs emerge from grits and conglomerates. The Baramasia and Lau-lau-dah springs are in the Rajmahal trap area.

5. *Coalfields.*—Several springs have been found along the east-west belt of coalfields, extending from the Raniganj field, in Manbhum, on the east, to the Hutar field in Palamau on the west, following mainly the valleys of the Damuda and Auranga riverr.

The more well-known springs are the following:

(*a*) Tathi (23° 41′ : 86° 48′), west of the Raniganj field, Manbhum.
(*b*) Sheopur or Sarsa Khund (23° 40′ : 86° 35′), east of the Jharia field.
(*c*) Indra Jurba, west of the Bokaro field.
(*d*) Kawa Gandhawani, southern edge of the Karanpura field.
(*e*) Jaram (23° 49′ : 84° 30′), north of the Auranga field.
(*f*) Kokraha (23° 45′ : 84° 05′), on the Hutar field.

Of these Indra Jurba and Kawa Gandhawani have been already noted under the Hazaribagh springs. Kokraha is actually on the Gondwanas, but the others are in the Archeans close to the coal-fields. Little is known about them except that most are sulphurous.

South of the coalfields belt hot springs are known to occur at several places.

Properties.

Of the springs mentioned above only the following have been subjected to recent investigation: the Rajghir springs in Patna district; the springs at Tapoban and Agni Khund in Gaya district; the Suraj

Khund, Kawa Gandhawani, and Duari springs in Hazaribagh district; and the springs at Sita Khund and Rishi Khund in Monghyr. At some of these places several springs have been examined, and the properties of twenty-three springs determined.

The radioactive and other properties of these waters are given in Table 33. It will be noted that they may be arranged into five groups, according to their degree of radioactivity. Each of these groups may be compared with waters of similar properties in Europe, which are used for the following purposes:

Group I.—Comparable with Caria, Portugal, Bad Gesteen, Austria, and Roman Well, Italy. Utilised solely for their radioactivity; said to cure gout and rheumatism of all forms, anæmia and weakness.

Group II.—Comparable with Büttel, Baden, and Pórla, Sweden. Utilised for the same purpose as Group I.

Group III.—Comparable with Hog, Sweden, Bath, England, and Apollinaris. Utilised both for their radioactivity and medical constituents.

Group IV.—Comparable with Droitwich, England. Utilised chiefly for their medical constituents.

Group V.—Comparable with Llandrindod Wells, Wales. Utilised for their medical constituents.

All of the springs listed in Table 33 have a local reputation for the cure of skin diseases, rheumatism, digestive disorders and inducement of appetite. The waters of Agni Khund, Gaya district, have a special reputation for the cure of skin diseases.

Chemical analyses have been made of all of these waters. With the exception of three, they show remarkably little mineralisation, and apart from slight alkalinity almost approach distilled water in purity. The springs at Kawa Gandhawani, Duari, and Suraj Khund, Hazaribagh district, are all well mineralised, the first two being also strongly radioactive. Analyses of these three waters are given in Table 34. From the point of view of medicinal constituents, the Duari and Suraj Khund waters are comparable with those of Aix-les-Bains. The Kawa Gandhawani water has no known European equivalents. From the analyses it will be noticed that they all contain quite an appreciable amount of fluorine. The presence of fluorine is frequently regarded as inimical in the use of waters for drinking purposes, and the effect of their presence in these waters should be investigated.

TABLE 33.—*Properties of Bihar springs.*

Spring.	Locality	District.	Radon content in mMc.	Rate of flow. (Gallons per hour).	Temperature Centigrade	Gas
		I.—SPRINGS OF VERY HIGH RADIOACTIVITY.				
Kawa Gandhawani .	Kanki .	Hazaribagh	9 51	1,150	35°	Slow H S bubbles.
Brahma Khund . .	Rajghir .	Patna .	6 8713	8,000	42·5°	Intermittent inert gas.
Chandrama Khund .	Do. .	Do. .	6·59	200	40°	*nil*
Suraj Khund . .	Do. .	Do. .	6·42	575	41°	*nil.*
Sita Khund . . .	Do. .	Do. .	6·20	200	10°	*nil.*
Brahma Khund . .	Tapoban	Gaya .	6 1022	766	47°	*nil*
		II —SPRINGS OF HIGH RADIOACTIVITY.				
Duari	..	Hazaribagh	3·28	500	45°	Intermittent H_2S.
Makhdum Khund .	Rajghir .	Patna .	4·13	1,436	36°	*nil.*
Vyas Khund . .	Do. .	Do. .	3·576	1,044	41°	*nil.*
Ganga Khund . .	Do. .	Do. .	3·58	760	42°	*nil.*
Jamuna Khund . .	Do. .	Do. .	3·60	415	41·5°	*nil.*
Agni Khund . .		Gaya .	4·234	9,000	50°	Frequent H_2S and CO_2 bubbles.
Sita Khund . . .	Sita Khund	Monghyr .	4·21	38,000	57°	Copious CO_2
Phillip's Khund . .	Do. .	Do. .	3·046	10,500	55°	Do.
Rishi Khund, South (F)	Rishi Khund.	Do. .	3·193	500	44°	Do.
Rishi Khund (H) . .	Do	Do. .	4·306	700	45°	Few CO_2 bubbles.
		III.—SPRINGS OF MODERATELY HIGH RADIOACTIVITY.				
Viswamitra Khund .	Rajghir	Patna .	1·38	1,436	41·5°	*nil.*
Markandya Khund .	Do. .	Do. .	1·73	125	39·5°	*nil.*
Ram Khund (hot) .	Do. .	Do. .	1·0035	55	32°	*nil.*
		IV.—SPRINGS OF MILD RADIOACTIVITY.				
Suraj Khund . .	Barkatta.	Hazaribagh	0·7478	3,000	87°	Continuous CO_2 and H_2S.
Sita Khund . . .	near Suraj Khund.	Do. .	0·72	feeble	27°	Slow CO_2.
Lachman Khund . .	Do. .	Do. .	0·905	100	66°	Intermittent CO_2 bubbles.
		V.—SPRINGS WITH NEGLIGIBLE RADIOACTIVITY.				
Ram Khund (cold) .	Rajghir .	Patna .	trace	10	23·5°	*nil.*

TABLE 34.—*Composition of medicinal waters.*
(In parts per million)

—		Duari.	Suraj Khund.	Aix-les-Bains.	Kawa Gandhawani.
Silica	SiO_2	68	128	5	36
Iron	Fe	*nil*	*nil*	4·2	*nil.*
Aluminium	Al	4·24	*nil*	8·7	11·4
Calcium	Ca	2·9	2·9	64	*nil.*
Magnesium	Mg	*nil*	trace	19	*nil.*
Sodium	Na	128	146	34	109
Carbonate	CO_3	121	123	112	185
Bicarbonate	HCO_3				
Sulphate	SO_4	38	65	151	7
Sulphide	S	20	..	34	..
Chloride	Cl	71	92	18	39
Fluoride	F	18	21	..	17
TOTAL SOLIDS		420	540	416	352
Gases	H_2S	Present	Present	Present	..
	CO_2	?	Present	Present	..
Detected by spectrum analysis		Potash Manganese Lithium Strontium	Potash Lithium Strontium		Calcium. Potash. Manganese. Lithium. Barium. Strontium.

Future development.

The springs listed in groups I and II compare favourably with the majority of the European springs for radioactivity, and far exceed the best English water from Bath. They could undoubtedly be used for the same purpose as such waters in other countries.

The waters of the radioactive groups I and II, with the exception of those from Kawa Gondhawani and Duari, possess little mineralisation. One of the springs of this group, at Phillip's Kund, is now being utilised for the manufacture of ærated water. To derive the maximum benefit from such radioactive waters, however, they should be used on the spot as the radium emanation is reduced to half in nearly three days and almost completely disappears in 30 days.

The Kawa Gondhawani and Duari waters, with their combined radioactive and mineral contents, should be of particular value, but

it would be advisable to investigate the possible harmful effect of the fluorine content. If advisable it may be possible to treat the water to eliminate this constituent prior to use.

All of these springs throughout the province should, wherever possible, be brought under State control for future exploitation.

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CHAPTER XXIX.

MINERAL WOOL.

General.

If mineral matter is fused and then blown by a blast of air or steam it is drawn out into fine fibres; this material has been given the name *mineral wool.* There are several varieties of this depending upon the composition of the original melt: glass melts give *glass wool* or *glass silk*, metallurgical slags give *slag wool*, and fused rock or mixtures of rock give *rock wool.*

Mineral wool was apparently first made in Wales and Germany about 1840. Later, in 1870, fibre made from glass and from furnace slag, was known as *mineral cotton* in the United States; it was not until 1896, however, that a plant was constructed in Indiana for manufacturing mineral wool. Since then the technique of manufacture has considerably improved, and, particularly in recent years, there has been a rapid growth of the industry. In 1936, the production of mineral wool in America had risen to 500,000 tons, having a sale value of $6,000,000, with 50 plants in operation.

Dr. Krishnan, of the Geological Survey of India, has recently drawn attention to the possibility of manufacturing this material in India. He has pointed out the need, in a tropical country like India, for a cheap insulating material which can be used in building construction.

Uses.

The value of mineral wool lies in its heat insulating property and this is due to the still air trapped between the fibres. Experiments have demonstrated that fibres with a diameter of 2-10 microns give the best results. Although not as good a heat insulator as asbestos it is amongst the best insulators. It is used for protecting water pipes, furnaces, stoves, boilers, retorts, smokestacks, ice boxes, refrigerators, etc. It is used also to deaden sound in buildings, as a filter for air and for certain corrosive liquids, and also as a packing against shock.

Mineral wool is put on the market in various forms according to the use for which it is required

Loose wool is the material as it emerges from the blowing room, and is used in that form for insulating buildings.

Granulated wool is made by passing the loose wool through granulators which break it up into short fibres. This is used for packing into walls, roofs, etc., by blowing it in through a hose with compressed air.

Batts are made by compressing the wool with a binder and cutting into suitable shapes for use in buildings, in such spaces as beneath floors, in walls, roofs, etc. They are sometimes made into continous rolls.

Blankets are rectangular shapes in which the wool is sewn between wire-netting, expanded metal, paper, etc., and may or may not be held together by a binder.

Tiles, bricks, boards and blocks are made by binding the wool with such material as asphalt, plaster, cement, etc., and moulding it into the required shape. They are used for such purposes as lining refrigerators and stoves.

Insulating cement is made by mixing the wool with such binder as clay, bentonite or cement, and is used around irregular objects, steam pipes, etc.

Dress fabrics, heat-resisting ropes, and fire-proof curtains have been made from the better soda-lime-silica glass wools.

Raw material.

The raw materials used in the manufacture of mineral wool include broken glass and china, sand, gravel, earth, slag, easily fused rock, shale and impure limestone. But the composition of the material used and the temperature and other physical conditions of manufacture should be kept under control in order that the product may be uniform.

In Bihar the slag from the blast furnaces at Jamshedpur might be used for the manufacture of slag wool after experiment. There are no natural rocks in the province which could be described as readily fusible. There are, however, many deposits of impure limestone and dolomite which could be used, with silica, for the manufacture of mineral wool, perhaps in conjunction with cement works.

Production.

The raw materials are heated in various types of furnaces: cupolas, reverberatory, or electrical furnaces. There are several methods of drawing into fibres. The simplest is to pour the melt in a thin stream across a jet of steam or air, which splits the melt into small globules which are then drawn by the blast into threads. Another method is to drop the molten stream on to a disc revolving at high speed; the droplets are thrown off as fine fibres. The melt may also be spun into threads on a rotating wheel or drum. Exceptionally long fibres may be produced by the latter method.

According to Fryling and White, to produce 2,000 lbs. of rock wool the following raw materials are required: 3,000 lbs. of rock, 1,200 lbs. of coke, 3,000 lbs. of steam, 4,000 gallons of cooling water. Accordingly cost of coke is a large item, but the U. S. Bureau of Mines has estimated that with coke at $ 4 to $ 5 per ton the cost of producing rock wool should be less than $ 20 per ton.

The possibilities of production in India might be investigated but careful research will be required on the various processes which could be used before any practical success is likely.

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CHAPTER XXX.

REFRACTORY MATERIALS.

General.

Bihar's resources in minerals which can be used for refractory purposes are both considerable and varied. Apart from the more common materials, clays and silica, which are used for the manufacture of refractory bricks, there are deposits of other minerals the properties of which permit them to be used for special refractory purposes.

A large and important industry has been built up in Bihar and just over the border in Bengal, utilising some of the province's resources in the manufacture of refractory goods. In other cases quite a considerable export trade has arisen in the despatch of refractory raw materials to other countries; no doubt, in the future, there will be an increasing tendency to work up these raw materials in the country and export the manufactured articles.

In this chapter the wider meaning of the term *refractory material* has been accepted, and includes all materials which are used because of their heat resisting qualities.

Bauxite.

As described in Chapter XII, the reserves of bauxite in Bihar are considerable. The uses of this material are varied, one application being in the manufacture of aluminous refractory bricks. Although bauxite bricks are manufactured in India from Bihar bauxite, the production is limited almost entirely to the requirements of local industry. At present the prospects of developing an export trade in bauxite bricks do not appear to be favourable.

Chromite.

Amongst the several purposes described in Chapter XIV for which chromite can be used, one of the most important has been as a neutral refractory. The manufacture of chromite bricks is rather more difficult than is the case of most other refractories and considerable skill is required in treatment in the kilns. Chromite bricks

have been successfully made in India, at least equal in quality to chromite bricks elsewhere. For this purpose the chromite from Singhbhum is not so suitable as the chromite from Baluchistan or South India. Possibly the reason is connected with the fact that the inter-grain matrix in the Singhbhum ore is serpentine, as distinct from the magnesite matrix of the South Indian and Baluchistan material. The iron content is another factor of importance, as chromite with a high iron content is unsuitable.

Fireclays.

The extensive refractory industry of Bihar has been based principally upon the excellent deposits of fireclays which occur in the Gondwana rocks of the coalfields. The occurrences of these clays have been described in sufficient detail in the general account of clays provided in Chapter XV. Resources of fireclays in the province are such that the industry is certain to continue to expand in the future, and there is little doubt that the requirements of metallurgical and other industries in the country can be fully met by locally produced firebricks.

Dolomite.

True dolomite consists of calcium and magnesium carbonates in equal molecular proportions. theoretically 45·65 percent $MgCO_3$ and 54·35 percent $CaCO_3$, but usually the proportion of $CaCO_3$ is greater. The term dolomitic limestone is commonly used for limestones with between 10 and 40 percent $MgCO_3$.

After calcining to the "deadburned" condition at 1500°C, these rocks are used for refractory purposes in basic open-hearth furnaces and in Bessemer converters, either as a plaster or in the form of bricks. Dolomite is also used for fettling furnace walls. Dolomite may eventually take the place of magnesite as a refractory for steel smelting. Dolomite bricks are prone to disintegrate as a result of hydration of the free lime when the furnace is cold. In a recent process the lime is converted to a calcium silicate by adding magnesium silicate and the product stabilised against inversion by the addition of chromic oxide. The talc-magnesite-rock near Bhitar Dari, south of Jamshedpur (see page 211), may be experimented with for this purpose.

The known resources of dolomitic limestone available in Bihar are small, but others may be found, particularly in Palamau where they are known to occur associated with limestone southwest of Daltonganj (see page 167).

Just to the north of Chaibasa in Singhbhum, there is a deposit of dolomitic limestone interbedded with the Iron-ore Series at Putada spring (22° 34′ : 85° 49′) an analysis is given in Table 35.

TABLE 35.—*Dolomite from Putada spring, Chaibasa.*

	Percent.
SiO_2	2·50
Al_2O_3	1·66
Fe_2O_3	0·24
CaO	32·69
MgO	15·96
Na_2O	0·88
K_2O	0·13
MnO	trace
Loss on ignition	45 52
	99·58

In the Vindhyans of Shahabad district a band of hard dolomitic limestone containing 16·5 percent MgO (35 percent $MgCO_3$) occurs in the Rohtas stage in the vicinity of Banjari (24° 41′ ; 84° 00′).

Graphite.

Attempts have been made to manufacture graphite crucibles in India. The quality of the material does not, however, appear to reach the standard used in imported graphite crucibles. One of the reasons advanced is that Indian graphite contains much mica, which lowers its fusibility.

Micaceous graphitic schists containing disseminated small flakes and segregations of the mineral up to 1 inch in size have been found at Arapur (24° 14′ : 84° 02′), Tulbula (24° 15′ : 84° 02′), and Hatai Khas (24° 14′ : 84° 01′) near Daltonganj(1). A fragment of graphitic gneiss has been recorded from the bed of the Koel river near Hutar, Palamau district. After picking, a sample of graphite from Baghmari (24° 48′ : 86° 45′), 4 miles north of Katauria, Monghyr district, assayed 64 percent carbon(2). Graphite has also been recorded at Dimadiha (23° 29′ : 86° 09′) in Manbhum.

In North Singhbhum, South Ranchi and South Manbhum beds of carbon phyllite are associated with the Dalma lavas(3). There are quite extensive areas of phyllite in which the content of amorphous carbon is very high. Whether the grade of these deposits could be improved by dressing, and whether the dressed material would be marketable, might be worth investigating.

Kyanite.

Apart from its use in high-grade ceramic ware, the greater part of the output of kyanite is used for refractory purposes, particularly in furnaces where temperature fluctuation and other conditions are severe, as in glass furnaces. In view of its ready fusion with metallic oxide slags it may not be used in contact with molten metal. The Bihar occurrences of this mineral are described in Chapter XXI. Although the deposits in Bihar proper will have only a very limited life, the resources in the adjacent State of Kharsawan, at Lapsa Buru, worked by the Indian Copper Corporation, are great.

There seems no real reason why the manufacture of refractory bricks made from kyanite should not increase considerably in the near future in India, instead of permitting the export of almost the entire output of the raw material. It is largely a question of local demand, but should the glass industry expand, then requirements of high-grade refractory should increase.

Magnesite.

The magnesium carbonate, magnesite, is a valuable neutral refractory, used particularly in steel smelting. So far no substitute has been found for it, although it is not improbable that dolomite may replace it eventually. In India deposits of magnesite occur in South India and in Idar State; if any deposits could be found in Bihar they would be of great value to the steel industry.

No deposits of pure magnesite are known in Bihar. On the hills northwest of Bhitar Dari (22° 41′: 86° 11′), in Singhbhum, there is a large deposit of talc accompanied by magnesite(4); in places this magnesite forms a very considerable proportion of the rock, but none of sufficient grade to be of economic importance has been seen. A thorough prospecting of this deposit may be worth while.

Quartz-schist.

Quartz-schists and quartz-granulites are quarried in Bihar for use by the steel industry in lining the Bessemer converters and, for this purpose, they are practically equivalent to the gannister used in England. The main quarries are in Singhbhum where the Tata Iron and Steel Company have opened up many quarries between Rakha Mines (22° 38′: 86° 22′) and Kendadih (22° 35′: 86° 25′). The quartz-schists and granulites here (5) are the beds in which segregations of kyanite are found (see Chapter XXI).

Silica.

Silica, in the form of quartz, is extensively used in the refractory industry for the manufacture of silica bricks. These bricks are used particularly in the construction of coke ovens and in the roofs of steel furnaces where the conditions of rapid alternations of temperature would disintegrate ordinary firebrick. For this purpose a rather pure crushed quartzite is used, of which there is a plentiful supply in the Archean quartzites of Gaya and Monghyr districts. Messrs. Burn and Co. are quarrying quartzite for silica bricks from the foothills of the Kharagpur hills close to Jamalpur (25° 18′: 86° 29′).

A small amount of silica, in the form of quartzite, is also used in the manufacture of porcelain bodies. Most of this is obtained from near Jamtara on the E. I. Rly.

Silica in the form of sand is also used as moulding sands in foundry work. River sands such as those along the Damodar may be used, or sometimes crushed sandstones, or even vein quartz.

Steatite.

One of the uses of steatite is as a refractory material in small furnaces and stoves, and in recent years the mineral has found an increasing application as a lining in alkali smelting furnaces in paper mills, where resistance to alkaline slags is essential. It also finds a wide use in gas burner tips.

As noted in Chapter XXXII, deposits of this mineral are by no means inconsiderable, and most of them yet await investigation and development for modern purposes.

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CHAPTER XXXI.

SAND.

General.

A very large amount of sand is absorbed in a wide variety of industries. No statistics of sand production are available in India, but the quantities used in building, road-making, stowing in coal mines, and the glass industry, must run into many thousands of tons each year.

Sands occur as detrital deposits. In Bihar they are found usually along the stream beds, and in North Bihar extensive beds of sand are known to immediately underlie the surface over wide areas, particularly in Purnea district. As a rule sand grains range in size from 0·02 inch to 0·2 inch ; above the latter size they grade into grits and gravels. Sometimes soft friable sandstones which can be readily crushed are used as sands.

Most river sands are rather impure. The main constituent is, of course, quartz grains, but in addition grains of felspar, mica, argillaceous material and iron oxide are commonly present, with frequently very small amounts of other minerals.

As a rule sand requires a certain amount of treatment before it may be used. For many purposes it must be sized by sieving through a series of screens. Washing may also be necessary to remove clay material, mica, and organic matter. For certain purposes, such as in the glass industry, the sand must be of a particularly high degree of purity.

Uses and properties.

In the near future, perhaps the greatest use of sand in Bihar will be for stowing in coal mines. For this purpose purity will be immaterial, as also will size within limits.

For building purposes in mortars and concrete a clean sand is preferred, and usually a sharp sand, that is, one with angular rather than rounded grains. For use in road construction a clean sand is not essential, and close screening is not necessary.

The properties of glass sands have been described in Chapter XVIII. Purity and reasonably close sizing is here essential,

and for this reason sands which are suitable for this purpose are rare, and they are commonly obtained by crushing friable pure sandstones.

A large amount of sand is required by foundries, as moulding sands in which the metal is cast. Sand for this purpose must have special properties, and is used mixed with other materials. The moulding sand after mixing must have cohesiveness in order to retain the shape of the pattern, and naturally it must be sufficiently refractory not to be fused by the molten metal. Gases are given off by the molten metal, so that the moulding sand must be sufficiently permeable to allow the escape of these. As a rule large castings are cast in moulds made from a coarser sand than is used for small castings. The moulding sand mixture varies also for the type of metal to be cast. For iron a very high quality sand is not essential, a good cohesiveness is the main property. For steel castings a good quality fine sand is used with special binders such as bentonite. For casting aluminium, lead, copper, brass or bronze, particularly if great detail is essential, a very fine sand must be used with a special binder. All foundries have their own moulding mixtures which are invariably the result of considerable experiment.

Other metallurgical applications of sands are for lining and patching certain furnaces, cupolas, ladles and vessels that are used for holding molten metal. For these purposes a high-grade material is necessary.

For the manufacture of ferro-silicon a very pure quartz sand of even grain-size is essential.

For the manufacture of refractory silica bricks and for use in ceramic ware a very pure silica sand is necessary; accordingly detrital sands are rarely used, and crushed sandstone or quartzite is the main source.

Sands are used for filtering water. For this purpose they should be free from clay and organic matter, and the grains should be evenly sized. Some sands contain a high proportion of heavy minerals like magnetite, ilmenite, rutile, etc., and in certain filters, on agitation, these heavy grains settle to the bottom and soon become difficult to clean in the reversed cleaning current.

For abrasive purposes, such as for cutting and dressing stone and for sandblasting, the quartz grains may be either rounded or angular and, of course, not high in impurities. For making sandpaper a crushed sand is required. In the manufacture of silicon carbide a pure quartz sand is essential.

Finely ground sand is used for many purposes, such as a filler in paint, in special plasters, as grit for poultry, in tooth pastes cosmetics and dental powder, for frosting glass, and in soap and polishes. For these purposes a pure material is required, so that quartz from quartz veins or from mining operations is used instead of detrital sands.

Distribution.

In the future, enormous quantities of sand will be essential for sandstowing in Bihar coal mines. According to L. J. Barraclough, at the Parbelia, Sitalpore and Sodepore collieries on the Raniganj field, quantities exceeding 2,000 tons per day are required; for collieries on the Jharia field several million tons per year will be needed. It is proposed to take most of this sand from the Damodar river where it passes through the coalfield, and there has been considerable discussion in recent years whether the river is capable of replenishing, during the monsoon period, the sand taken from its bed. However, vast quantities of sand occur throughout the many miles of river bed upstream. Removal of sand from one place will mean a temporary increase in gradient above the excavation, permitting a more rapid movement of sand, so that annual replenishment in the excavated area should be great. Whether this replenishment during the monsoon months will keep pace with the annual extraction cannot be judged by simple experiments on a small scale, nor from calculations of the carrying capacity of the river current, such as have seen attempted. All that can be said is that replenishment will be very considerable indeed in normal monsoons, and that the amount available for annual extraction can be determined only by actual working.

For glass-making purposes the river sands of Bihar are not sufficiently pure, except for the manufacture of inferior qualities such as bottle glass. Even for this purpose there are few places along the river beds where the quality of the sand would remain consistent after successive monsoons.

For foundry purposes local sands are used. Sands for other purposes, such as for the building trade and for filters, are obtained as near as possible to the site where they are to be used. There is, perhaps, scope for a rather detailed examination of the sands of

Bihar to determine their composition and suitability for certain purposes, and for the eventual establishment of such industries as the manufacture of abrasives.

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CHAPTER XXXII.

STEATITE (SOAPSTONE).

General.

For many centuries various talcose stone materials have been used in Bihar and other parts of India for the manufacture of dishes and cooking pots, and for carving into ornaments and images. In Singhbhum soapstone utensils were used by the ancients in their copper smelting practice. Quite a variety of materials have been used most of them being some form of magnesian silicate, such as soft chloritic schists and altered igneous rocks, but the majority are of an impure form of steatite (soapstone), the fine-grained massive variety of the mineral talc. All of these materials have, in the past, been included under the designation "potstones". Occasionally quite pure soapstone and talc-schist have been used for this purpose.

The trade in these potstones in Bihar is still carried on although considerably diminished. Cooking utensils of potstone are still in request by high-caste Hindus, since they can be purified by fire after use, and they communicate no unpleasant taste to food. It is not possible to obtain details of the exact extent of the trade, the recorded quantities in Table 36 represent only a fraction of the industry.

TABLE 36.—*Production of steatite.*

Year.	Bihar.		India.	
	Tons.	Rupees.	Tons.	Rupees.
1929	434 (*a*)	19,211	7,217	2,76,483
1930	261 (*a*)	8,086	6,857	2,06,086
1931	506 (*a*)	11,346	5,135	1,21,508
1932	152 (*a*)	760	6,512	1,29,490
1933	1,114 (*a*)	10,284	17,048	1,82,964
1934	285 (*a*)	1,530	9,375	1,70,239
1935	1,406 (*a*)	17,203	12,596	1.91,663
1936	1,699	10,241	9,968	1,56,983
1937	1,000	5,965	13,040	1,55,221
1938	692	3,985	18,590	1,68,580
1939	955	5,591	22,259	2,03,841

(*a*) Includes production in Orissa.

Uses.

Besides their ancient use as a potstone the purer forms of soapstone and talc-schist have several more modern applications as a polishing medium and filler. As a refractory, talc is commonly used in the manufacture of gas burners as well as in small furnaces and stoves. Within recent years steatite bricks have come into increasing use where resistance to corrosion, especially by high alkaline slags, is necessary, for example in the Wagner alkali smelting furnaces at the recovery end of paper mills. In the powder form the mineral is widely used as a polishing agent for glass and leather and in rice milling, also in the manufacture of soap, as a foundry facing, as a filler in paint, paper and textiles, as a lubricant, and in the manufacture of certain wall plasters. It is sometimes mixed with china clay for pottery, apparently to increase the latter's resistance to thermal shock. Slabs are cut into panels for table tops, switchboards and tanks.

Distribution.

Although soapstone and talc-schist are widely distributed in Chota Nagpur, the best occurrences are in Manbhum and Singhbhum. As long ago as 1881, Ball mentioned twelve villages in Manbhum where potstones were quarried, between Maysara (23° 04′ : 86° 00′) and Khusbani (22° 48′ : 86° 34′).

In the hill-ranges extending along the whole of the northern border of Singhbhum, from the Ranchi border to Midnapore district, steatite and talc-schist deposits are consistently found. They vary from talc-chlorite-rocks, both massive and schistose, to deposits of almost pure fine-grained massive talc-rock. The larger deposits occur at the following localities: north of Kuddadih (22° 53′ : 85° 48′) and south of Bandudih (22° 55′ : 85° 49′), in Ranchi district; Belaipahari (22° 50′ : 86° 17′) and Digha (22° 39′ : 86° 32′) in Singhbhum (Dhalbhum); Pukhurkata (22° 52′ : 86° 38′) in Manbhum.

Parallel with the copper belt, extending west to east across Singhbhum into southeastern Dhalbhum, there is a series of soapstone and talc-schist deposits. Perhaps the best of these is in the hills northwest of Bhitar Dari (22° 41′ : 86° 11′) where the talc is accompanied by magnesite. At this place some old workings illustrate the excellent mining ability of the ancient people as compared with the mining practice of the present-day village soapstone workers. The

ancients exacavated neat round shafts off which galleries were driven according to a more or less systematic plan, but the present-day workers are content with squeezing themselves down into the narrowest warrens they can burrow. Other soapstone and talc-schist deposits along the copper belt occur between Rakha Mines and Kendadih (22° 35′: 86° 25′); at Rakha Mines, a borehole put down through the quartz-schist penetrated below for over 100 feet into quite good quality soapstone. Further south at Chirutanr (22° 24′: 86° 34′), northeast of Mahespur (22° 23′: 86° 30′), Khejurdari (22° 24′: 86° 33′), Burudih (22° 22′: 86° 31′), Dongadaha (22° 21′: 86° 34′) and west of Banmakri (22° 18′: 86° 37′), other outcrops of talc-rock occur. Just north of the copper belt, at Mahulisol (22° 28′: 86° 34′), is one of the largest deposits of soapstone in Singhbhum.

Further south from the copper belt there is a group of talc deposits in the rocks extending south from Manpur (22° 36′: 86° 16′), and also in the range of hills on the Dhalbhum-Mayurbhanj border, striking northwest from Kundarkocha (22° 27′: 86° 15′), especially near Raghabdih (22° 31′: 86° 07′) and Kuardih (22° 33′: 86° 05′).

Soapstone is found associated with the rocks of the chromite area west of Chaibasa, and quite extensive deposits, associated with ultrabasic rocks, have been quarried at Nurda (22° 20′: 85° 44′), 18 miles south of Chaibasa.

In Shahabad district a dark blue potstone is said to occur at Pittian and other localities along the north face of the Kaimur plateau, forming a bed 30 feet thick overlying alum shales.

In Gaya district a chloritic potstone has been obtained in some small hills lying between the Rajghir and Barabar hills.

Deposits of steatite are worked in Hazaribagh, to the west of Parasnath. Bricks cut from this material have been used in the alkali furnaces in paper mills. Similar deposits have been worked in the Pandra Kismat Estate (23° 48′: 86° 43′), Manbhum.

Dr. Dey has reported that phyllites north of Budhraisahi (22° 40′: 86° 35′) in Singhbhum and west of Burijhor (22° 40′: 86° 39′), are used as potstones and turned on lathes into utensils.

Mode of occurrence.

The soapstone deposits in the belt extending along the northern border of Singhbhum have been formed by the alteration of the Dalma lavas and ultrabasic igneous rocks, and also of chloritic phyllites derived from basic tuffs of the Iron-ore Series.

The deposits occurring along the copper belt are nearly all altered basic igneous rocks, lavas and intrusives, some of the latter being ultrabasic. A few of the deposits are derived from tuffs. The remaining deposits in southern Dhalbhum have all been formed by the alteration of basic and ultrabasic rocks.

The soapstones of the chromite area in the Kolhan are the altered products of ultrabasic rocks.

Although the original rocks from which these talc-rocks were derived in Singhbhum are of several types, the great majority are basic to ultrabasic igneous rocks. The alteration of these to form soapstone implies the removal of a great amount of material to leave almost pure magnesian silicate. The alteration is presumably associated with the solutions given off from the granite which intruded the Iron-ore Series.

Future.

There has never been any serious attempt to develop any of the Singhbhum soapstone for use as a modern refractory, or for grinding into powder suitable as a polisher or as a filler for paper and textiles. To date, it has been entirely an indigenous industry of merely local importance, supplying utensils for local use.

The soapstone resources of Singhbhum are enormous and widely distributed, many of the localities are very accessible to the railway, and there are no closer deposits to Calcutta. Details of market requirements are lacking, but it should be possible to expand the applications of this mineral and to open up a wider market in certain instances where kaolin is at present used. In consequence of its accessibility, Singhbhum soapstone would be in the position to supply all the requirement of eastern India.

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CHAPTER XXXIII.

SULPHUR.

General.

Although India is reasonably well endowed with resources of most mineral raw materials, one of the most important minerals, sulphur, is deficient. Sulphur is required in many industries, and its most important uses are in the manufacture of sulphuric acid, chemicals, tin plate, fertilisers, paper, explosives, dyes and coal-tar products, rubber, paint and varnish, food products and acid-proof cements.

Practically the entire Indian requirements of sulphur are imported. Small quantities have been obtained from the dying volcano of Barren Island in the Bay of Bengal, and the sulphur mine near Sanni in Kalat State, Baluchistan, also yielded small amounts years ago. Deposits have recently been found on Koh-i-Sultan, Baluchistan. Probably, in the future, a process will be developed for the extraction of the sulphur content of the gypsum deposits (hydrated calcium sulphate) of northern India. From time to time the possibility has been considered of recovering, as a by-product, part of the sulphur given off in the smelting of sulphide ores, and also of mining pyrites deposits for use as a source of sulphur.

Some years ago it was suggested that zinc concentrates from Bawdwin mines, Burma, should be treated at Jamshedpur instead of being shipped to Europe, and the sulphur recovered as a by-product in the form of sulphuric acid. This project was never carried through.

The recovery of sulphur from the flue gases at the works of the Indian Copper Corporation has been carefully considered by the company's staff, but, under present technique, it would be practicable to recover only the gases from the roaster, in the form of sulphuric acid and, to be an economic proposition, this would need to be used by a chemical industry at Ghatsila. About one-third of the ore is roasted, and the sulphur dioxide from this roasted portion could provide 20 to 30 tons of 100 percent acid per day.

Endeavours have been made to locate deposits of pyrites in India, but, although small occurrences of the mineral of purely mineralogical interest are common enough, nothing had been found which offered hopes of commercial success until recently. However, likely

deposits have been found in Shahabad district, and the following information is from notes by Mr. J. B. Auden of the Geological Survey and the writer.

Sulphur in Shahabad district.

Iron pyrites is found at the top of the Bijaigarh shales of the Kaimur series, Vindhyan system. These shales occur half way up the scarp slopes of the Kaimur plateau on the left bank of the Son river, east of longitude 84° 00′ and south of latitude 24° 50′.

The pyrite occurs in black carbonaceous shales within about 30 feet from the base of the Upper Kaimur sandstone. Normally the mineral occurs only as small scattered crystals, but locally the pyritic content of the shales increases to about 10 percent (5·3 percent sulphur), when the shale has a sub-metallic lustre. Such shales are well seen in the Mahadeo nala about 1½ miles west of the Baulia quarries of the Son Valley Portland Cement Company.

In addition definite seams of pyrites are known at three localities :—

(*a*) Am Jor; (*b*) Kasisya Koh; (*c*) Yogyaman Koh.

The seams of the first two localities were known over 130 years ago and the efflorescence of iron sulphate (known as *kasis*) which forms on their surface was worked by indigo planters. The localities were mentioned by Martin in 1838. The Am Jor locality was recently rediscovered by Babu Madan Lal, of the Kuchwar Lime and Stone Co., while J. B. Auden, on the basis of Martin's account, re-found the Kasisya Koh deposit and found the seam at Yogyaman Koh.

Am Jor. The seam of pyrite occurs by a tributary of the Am Jor, at a height of 700 feet above sea level, three miles from Banjari on the Dehri-Rohtas Light Railway, at the position 24° 43′ 15″ : 83° 58′ 45″. It occurs 20 feet below the top of the black shales and has been exposed for 120 feet along the outcrop and for 115 feet into the hill. It varies from 18 inches to 36 inches in thickness, the average being perhaps 2 feet. The seam is practically horizontal with perhaps a slight inclination west. Some of the overlying shales carry a little pyrite with thin seams 3-6 inches thick. Representative analyses of samples taken across the seam are given in Table 37 but the average grade in mining has been found to be about 35 percent S.

TABLE 37.—*Analyses of pyrites.*

	Percent.	Percent
Sulphur	45·75	46·29
Iron	39 72	41·02
Copper	*nil.*	*nil.*
Arsenic	*nil.*	*nil.*
Pyritic content	85·5	87·0
Sp. gravity	4 2	4·6

The extent of the seam could easily be proved by driving galleries to its limits.

The pyrite is readily susceptible to decomposition.

Kasisya Koh. There was formerly a small quarry for pyrites in the Kasisya Koh (24° 41′ : 83° 53′), distant by bullock cart about 8 miles from Rohtas station. The quarry is now flooded but from data given by Martin it is probable that the thickness of the seam is 2 feet, and that it occurs about 14-16 feet below the top of the Bijaigarh shales which are exposed here for a distance of 71 feet along the strike. North and south of the outcrop the shales are covered by a heavy overburden of sandstone blocks.

Yogyaman Koh.—Another exposure of pyrites was found recently in the Yogyaman Koh (24° 43′ : 83° 52′), distant about 10 miles from Rohtas railway station. The seam is 3-4 inches in thickness and is exposed for 13 feet along the strike, but from oxide at the surface its total outcrop is about 80 feet. It is about 2 feet below the top of the Bijaigarh shales. The pyritic content of the seam where exposed is about 55 percent.

Future development.

It would be unwise to assume that the seams are continuous between the three localities mentioned in Shahabad district, as the individual seams are obviously lenticular and local. Other seams, as yet undiscovered, almost certainly occur.

It is apparent that the upper part of the Bijaigarh shales should be prospected wherever they crop out. Prospecting will be difficult on account of the great overburden of fallen blocks of Upper Kaimur sandstones which lie upon the Bijaigarh shales. Amongst the best places to look for pyrites are along nalas and below waterfalls at the foot of the Kaimur scarp. Indications of the pyrites are given by a porous red cindery oxidation product, but in the absence

of this there may be a dense growth of white feathery crystals of ferrous sulphate.

Until these shales are thoroughly prospected and opened up it is not clear whether sufficient reserves are available on which to found an industry in Bihar for the manufacture of sulphuric acid. It can, at least, be said that the evidence available warrants further development of the Am Jor deposit, providing there is a possibility of a market being found for the pyrites.

Reports of pyrites in Chota Nagpur are common enough, *e.g.*, in Manbhum and Ranchi districts, but the deposits are too small or too low-grade to be workable.

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CHAPTER XXXIV.

VANADIUM.

General.

Most of the world's supply of vanadium has come from Minasragra in Peru, Broken Hill in Northern Rhodesia, and Abenab and Tsumeb mines in Southwest Africa. Small amounts have been found in U.S.A., Turkestan and Australia. Its occurrence in minerals in India is now known at two localities, one in Bhandara district, C. P., where it is one of the constituents of a green mica, the other in Singhbhum and adjacent Mayurbhanj where it is associated with magnetite and ilmenite.

The principal use for vanadium is in the metallurgical industry, as a toughener in steel, copper and aluminium, but it finds a minor use as a catalyst in the manufacture of sulphuric acid, in the manufacture of aniline black used in indelible ink, as a photographic developer and sensitiser, in medicine, in making paint driers, as insecticide, fungicide and fertiliser, in the guilding of pottery, and in the glass industry where its efficiency for filtering out ultraviolet rays is useful. In vanadium steel only a very small amount of vanadium is required, about 0·25 percent, although in high speed steels the amount may be increased to 1·75–2·3 percent.

Singhbhum occurrences.

Veins and segregations of titaniferous iron ores have been found in southern Dhalbhum, on Kotwar Pahar (22° 31′ : 86° 19′), around Dublabera (22° 29′ : 86° 17′) and Lango (22° 30′ : 86° 18′) villages, southwest of Kudarsahi (22° 29′ : 86° 17′) and south of Sindurpur (22° 28′ : 86° 15′). Other deposits occur over the border in Mayurbhanj State, where the largest deposit of all occurs at Kumhardubi (22° 17′ : 86° 19′).

In Dhalbhum recent developments have shown the veins and lenses to be up to 60 feet in thickness and up to 900 feet in length. Several of the deposits have recently been opened up by the Dublabera Mining Co. At Kumhardubi in Mayurbhanj over one million tons occur at the surface.

The veins and lenses do not crop out noticeably, but their presence is indicated by abundant debris scattered on the surface. They occur in gabbro and its ultrabasic variants.

The ore consists of a fine mixture mainly of magnetite, ilmenite, hematite, and a new mineral named coulsonite which is an iron-vanadium oxide. Rutile and goethite also occur occasionally. The vanadium oxide (V_2O_3) content of the ore varies from 0·50 to 4·84, and analyses showing as much as 8 percent have been recorded.

Future.

Vanadium-bearing titaniferous iron-ores have not as yet been utilised for the commercial extraction of vanadium. The treatment of such ores is likely to develop along either of two lines: (*a*) the direct smelting of the ore to form a ferro-vanadium alloy or (*b*) the extraction of V_2O_5 and TiO_2 by a wet process.

Very recently there have been reports that successful processes have been developed for the treatment of these ores. If this should prove correct then the deposits of Dhalbhum and Mayurbhanj would certainly repay further investigation and development. If the steel industry in India should embark on the smelting of special alloys research work on the use of these ores should well repay the time and expense involved. It should be remembered that the world's resources of vanadium are not great, the reserves of the largest deposit, Minasragra in Peru, are only about 15,000 tons of metallic vanadium. It is certain that some time in the future the Indian ores will be utilised.

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CHAPTER XXXV.

MINERAL OCCURRENCES OF LITTLE OR NO ECONOMIC VALUE.

Aluminium sulphate.

In 1838 Martin recorded that impure sulphate of alumina (*salajit*) occurred as an exudation on a cliff face near Hangriyo (? Hanriya, 24° 57′: 85° 24′) in the Rajghir Hills, Gaya district (1, p. 254). The material was sold locally as a medicine. Small quantities of alum have been obtained in the past from beds of alum shale near Rohtasgarh (24° 38′: 83° 55′) in Shahabad district(2); the alum is derived from the pyritic minerals in the shale which, according to Martin, is 10 feet thick (1, p. 529). The industry was obviously a very small one, and has disappeared. Its resumption would appear to be unlikely (1, 2, 3, 4).

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Antimony.

Deposits of lead-ore(1) at Hisatu (24° 00′: 85° 01′), Hazaribagh district, were reported to have been worked for antimony about the close of the 18th century(2). Specimens of ore obtained in 1842(3) were variously recorded to contain 4·7 percent and 12·2 percent antimony(4, 5). The deposit does not appear to have received further attention. As with so many of the lead occurrences in Bihar it was presumably a small pocket.

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Arsenic.

Specimens of lollingite, an arsenide of iron, including leucopyrite, are occasionally found in the mica-pegmatities of Hazaribagh district (1, 2, 3). These are only of mineralogical interest, however, and have no economic value.

1. Holland, T. H. The mica deposits of India. *Mem. Geol. Surv. India*, XXXIV, p. 51, 1902.
2. Coulson, A. I. Leucopyrite from Kodarma. *Rec. Geol. Surv. India*, LXI (2), p. 206, 1928.
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Beryl.

Beryl, a silicate of aluminium and beryllium, is the source of the metal beryllium which is used for the manufacture of copper-beryllium alloys. The mineral contains 12-13 percent of BeO, and has, in the past, been sold in Europe for £10 per ton *c.i.f.*; the alloy has been sold in recent years for about £5 per pound of beryllium content, the cost of manufacture being very high. Most of the world's production of beryl has come from Rajputana where it occurs in pegmatites. Crystals of beryl have been found in the mica pegmatites of Bihar, but they are comparatively rare. It is difficult to say how much could be made available if collected, most of it is now thrown on the dump heaps, unrecognised, but it is possible that if the mica miners were taught to recognise the mineral a few tons might be collected each year. It is doubtful whether such a small quantity would be worth attention.

Bismuth.

Two bismuth minerals, bismuthinite and bismuto phaerite have been recorded associated with specimens of barytes from Malthol (23° 26′ : 86° 26′) in Manbhum(1). They are of academic interest only. Slight traces of bismuth occur in the Singhbhum copper ores(2).

1. Dunn, J. A. Bismuthinite and bismutosphaerite from Manbhum. *Rec. Geol. Surv. India*, 73(2), 299-300, 1938.
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Columbite and tantalite.

The niobates and tantalates of iron and manganese, columbite and tantalite, have been found occasionally in the pegmatities of the mica belt. In Gaya district columbite has been recorded from

Abraki Pahar, near Singar (24° 34′ : 85° 30′), associated with pitchblende, triplite and monazite(1). In Hazaribagh district, specimens of columbite were found in 1897(2), in the Kodarma Reserved Forest. In Monghyr district specimens of columbite and tantalite containing 37 and 52 percent of Ta_2O_5 have been obtained from Pannoa hill near Jhajha (24° 47′ : 86° 26′) in a coarse pegmatite(1, 3).

1. Holland, T. H. Quinquennial review of the mineral production of India. *Rec. Geol. Surv. India*, XLVI, p. 284, 1915.
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Corundum.

The reported occurrences of corundum in Bihar have proved to be merely of mineralogical interest. None have been worked for use as an abrasive.

The first reported occurrence was by Row, in 1844, who mentioned that the mineral was found at Tutki Ghat (23° 57′ : 85° 42′) to the east of Hazaribagh(1). An occurrence mentioned by Hunter in 1875, among the hills to the northeast of Jamui, Monghyr district, has never since been confirmed(2). Interesting specimens of corundum were found by Warth near Salbani (23° 04′ : 86° 17′), Manbhum, in 1896(3). In this last locality the mineral occurs as blue crystals up to ½-inch diameter in coarse kyanite which forms small veins in mica-schists within a belt some 7 mines in length(4).

Fine corundum(5) is associated with some of the kyanite-rock in Singhbhum (see Chapter XXI). Its presence raises the alumina content of the kyanite-rock thus increasing the latter's value as a refractory material. It is, however, nowhere abundant in this rock and no corundum segregations have been found which could be used as an abrasive.

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Fuller's earth.

Fuller's earth was reported by Ball(1), in 1877, to occur in association with the pottery clays of Patharghatta hill (25° 20′ : 87° 17′), Bhagalpur district. He mentioned that it is known locally as *sabun-mitti* (soap earth), and was sold in the Calcutta bazars as *Rajmahal mitti*.

Fox(2) has reported that some of the clays associated with bauxite deposits in Ranchi district, as on Bagru (Dudmatia) Pat (23° 29′ : 84° 36′), have some of the properties of fuller's earth.

1. Ball, V. Geology of the Rajmahal Hills. *Mem. Geol. Surv. Ind.*, XIII, p. 240, 1877.
2. Fox, C. S. The bauxite and aluminous laterite occurrences of India. *Mem. Geol. Surv. India*, XLIX (1), p. 170, 1923.

Gemstones.

Agate, amethyst, etc.—Although varieties of agate, chalcedony, amethyst, and rock crystal may be found in the amygdaloidal basalt of the Rajmahal hills, there is no local industry for cutting and polishing these stones. Sherwill(1), in 1854, mentioned a bed of agate nodules extending for one mile from east to west, two miles to the north of Berhait (24° 53′ : 87° 37′). He also mentions geodes of quartz lined with amethyst crystals in a bed of chalcedony two miles to the west of the same village.

Apatite.—Beautiful clear green crystals of apatite have been found in a barytes vein near Malthol village, Manbhum. In the specimens submitted to the Geological Survey they were rather too small for cutting as gems, however.

Beryl.—Large greenish crystals of beryl, up to 3 ft. in length, have been found in the pegmatites of the mica belt. In very rare instances these are clear enough to be cut as cheap gemstones. Mallet(2) recorded the occurrence of small crystals in a pegmatite crossing the Tendwaha nadi south of Muhawar hill (24° 43′ : 85° 46′).

Corundum.—Crystals of blue corundum occur in kyanite veins near Salbani, Manbhum, but are not sufficiently clear to be classed as sapphire.

Diamonds.—Ball(3, 6) identified the village of Simah (23° 35′ : 84° 17′), in Palamau, with the village of Soumelpour of Tavernier(4) who stated that towards the end of the dry season about 8,000 persons were employed in washing the sands of the Koel river for diamonds. Likely places in the bed of the river were surrounded by a temporary dam, and the sand and gravel when dry was excavated

to a depth of not more than 2 feet, and carried to a shallow tank on the bank where it was thoroughly washed, and the gravel then spread out and searched for gems. Large stones were rarely found.

Blochman quotes a passage from the *Teezuk-i-Jahangiri*, which is believed to refer to a forgotten diamond field lying near the source of the Sunk (Sankh) river, to the south of the Koel watershed. Although diamonds of considerable value were said to have come from here, Hewitt, in 1887, remarked that none had been found for many years(5).

Garnets.—Along some of the streams traversing the mica-schists of northeast Dhalbhum, garnets occur, and until recently they were collected by the villagers near Malibani (22° 33′ : 86° 42′) for use apparently as an abrasive. Garnets may be often found in Hazaribagh, and they are quite abundant in some of the mica pegmatites. None of these are of the gem variety, however, and their use as an abrasive would not appear to be likely.

Jasper.—Quite attractive specimens of jasper may be occasionally found associated with the lavas and tuffs of the Iron-ore Series of South Singhbhum, in the vicinity of the iron-ore mines. Both green and red varieties occur.

Kyanite.—None of the pale blue kyanite of Singhbhum and Manbhum(7) is of sufficiently good colour or clearness to be used as a gemstone.

Rock crystal.—Rock crystals have been found in the Rajmahal traps, in vein quartz near Chaibasa, Singhbhum, and in geodes in the mica pegmatites.

Rose quartz.—Beautifully tinted rose quartz is often found in the pegmatites of the mica belt, particularly in the mines to the northeast of Parsabad railway station.

Tourmaline.—Although tourmaline is very abundant in the pegmatites of the mica belt it is only very rarely that a clear crystal approaching gem variety is found.

1. Sherwill, W. S. Geological and statistical report of the district of Bhaugalpoor, p. 48, 1854.
2. Mallet, F. R. Geological notes on part of Northern Hazaribagh. *Rec. Geol. Surv. India*, VII, p. 43, 1874.
3. Ball, V. Travels in India of Jean Baptiste Tavernier Baron of Aubonne. Vol. II, p. 81, 1889.
4. Tavernier, J. B. Collections of travels through Turkey, etc., Vol. 1, pt. 2, p. 139, 1684.
5. Hewitt, J. F. Chota Nagpore : its people and resources. *Is. Quart. Rev.*, III, p. 418, 1887.
6. Ball, V. Economic geology of India, (Diamonds), p. 24-37, 1881.
7. Mallet. F. R. Mineralogy, p. 13, 1887.

Molybdenite.

Flakes of molybdenite have been occasionally noted in the metamorphic rocks of Chota Nagpur, and in quartz veins. In Hazaribagh, rare flakes of the mineral up to an inch across have been found associated with the zinc-lead-copper-ores of Mahabank on the Patru river, in a matrix of coccolite and garnet. Some rare scales have been seen at the Baragunda copper mine, associated with copper and iron pyrites and sphalerite, in chloritic and micaceous schists. Flakes of the mineral have also been recorded from Umri (? Amra), near Dumri on the Damunia river. It is said to occur in metamorphic rocks in Manbhum. Dunn(1) detected a mineral resembling molybdenite whilst microscopically examining the copper-ores from Rakha Mines and Mushabani, Singhbhum. These occurrences are only of mineralogical interest and none are of economic value.

1. Dunn, J. A. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*, LXIX (1), pp. 42-43, 1937.

Monazite.

A considerable number of excellent crystals of monazite, a phosphate of the cerium metals, was found associated with pitchblende and columbite in the mica pegmatite at Abraki Pahar and near Pichhli, in Gaya district. A specimen assayed 9·95 percent ThO_2(1). Near Kanyaluka (22° 29′: 86° 31′) in Dhalbhum, a mineral intermediate between monazite and xenotime, yttrium phosphate, was found associated with apatite. The specimen assayed 6·92 percent ThO_2(2). Both occurrences are, of course, only of mineralogical interest.

[1] Tipper, G. H. On pitchblende, monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. *Rec. Geol. Surv. India*, L, pp. 259-260, 1919.

[2] Tipper, G. H. On a mineral related to xenotime from the Manbhum* district, Bihar and Orissa Province. *Rec. Geol. Surv. India*, LI, pp. 31-33, 1920.

(*Should be Singhbhum.)

Platinum.

Whilst panning for gold along the Gurma nadi near Dhadka (22° 48′: 86° 30′) in Manbhum, some years ago, Mr. E. O. Murray found silvery grains of platinum, the identification of which was later confirmed in the Geological Survey laboratory. The presence of the mineral along this stream was not confirmed by a more recent survey, and it appears that the grains found by Mr. Murray were entirely fortuitous.

Dunn, J. A. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*, LXIX (1), p 232, 1937.

Quartz crystals.

In consequence of the piezo-electric properties of certain quartz crystals, thin slices cut along definite directions in the crystals act as oscillators and resonate to alternating currents of particular frequencies, depending upon the thickness of the quartz slices. A number of such thin slices, of varying thickness, may therefore be used to separate currents of different frequencies sent simultaneously over the one transmission line. They find a considerable use, accordingly, wherever electrical oscillators are required, as in multiple telephony and telegraphy. They are also used for the control of frequency, in radio transmission.

The crystals required must be untwinned and have well-developed crystal faces; they should be at least 4½ inches long, and 2 inches in diameter, and be clear in transparency and free from flaws. Suitability can be determined only after expert examination.

No suitable crystals have as yet been obtained in Bihar, but there is always the possibility of crystals being found in such places as Singhbhum, on the mica belt, and associated with the traps of the Rajmahal hills.

Tin-ore (cassiterite).

The tin oxide, cassiterite, has been found in several places in Hazaribagh district. Within the mica belt crystals of the mineral have been found southwest of Pihra (24° 39′: 85° 49′), at Simratanri (24° 39′: 85° 47′) and at Chappatand (245° 40′: 86° 57′). Near Pihra the cassiterite occurs as small grains in a dyke of lepidolite granite. At Simratanri a few crystals of cassiterite were found by Mallet(1) in a lens of granite intruded into mica-schist. The Chappatand occurrence was brought to the notice of the Geological Survey by Mr. C. Jambon, and the material was described by Fermor(2); it consists of a cassiterite-granulite in which the cassiterite forms one-third to one-half of the rock, the other minerals being magnetite, quartz, felspar, a little hornblende, and biotite. None of these occurrences appear to be of more than mineralogical interest.

Another occurrence at Purgo (24° 10′: 86° 08′), in Palganj estate near Parasnath, was noted as long ago as 1849 by Mc. Clelland(3) when it was being smelted in village iron furnaces. According to Fermor(4) a thin layer of cassiterite granulite, up to 6 inches thick and containing 30-50 percent of cassiterite, occurs in a much

thicker band of microcline-granite which also contains scattered grains of cassiterite, especially close to the cassiterite-granulite. An unsuccessful attempt by European enterprise was made to work the deposit in 1867, and again in 1891-92 more serious mining was undertaken. According to Oates(5) an inclined shaft was sunk on the ore-band to a depth of 568 feet down the dip (about 25° to the E 10° N) where the ore-body cut out, although the incline was sunk further to 614 ft. The ore-band ranged in thickness from 18 inches to 6 inches. One sample from a full section across a level (15 inches of ore-band and the remainder wall-rock containing disseminated cassiterite) yielded 1·87 percent metal. Other samples assayed 2·1 to 6·2 percent metal. The mine was eventually abandoned through lack of funds. The deposit was again examined in 1909-10 and the surface portion was worked with the production of 3 cwt. of tin during each of the years 1909-10; a further 0·1 cwt. in 1914, and 0·7 ton in 1915 were extracted in native iron furnaces.

From the above information it is difficult to assess the prospects of reopening the mine. But it is evident that if it were reopened only a very short life could be expected.

1. Mallet, F. R. Geological notes on part of Northern Hazaribagh. *Rec. Geol. Surv. India*, VII, pp. 35, 43, 1874.

2. Fermor, L. L. Cassiterite granulite from the Hazaribagh district, Bengal. *Rec. Geol. Surv. India*, XXXIII, pp. 235-236, 1906.

3. Mc. Clelland, J. Report of the Geological Survey of India for the season 1848-49, pp. 19-20, 1850.

4. H. H. Hayden. General report of the Geological Survey of India for 1911, *Rec. Geol. Surv. India*, XLII, p. 79, 1912.

5. Oates, R. The copper and tin deposits of Chota Nagpore, Bengal, India. *Trans. Fed. Inst. Min. Eng.*, IX, pp. 445-451, 1895.

Titanium.

The greater part of the world's supply of titanium comes from the Travancore coast in South India, where, in recent years, the output of ilmenite sands, from which titanium oxide is extracted, has risen to over 200,000 tons per annum. The entire amount is exported for treatment overseas. In Bihar small occurrences have been reported but it is doubtful whether any of them are of economic value. In this province titanium is represented by two minerals, rutile, an oxide of titanium, and ilmenite, an oxide of iron and titanium.

Titanium oxide finds a wide use in brush and spray lacquers; it is a most valuable filler and pigment because of its covering

power, perfect whiteness and almost complete inertness. It is also used as a pigment in the plastic industry, in bakelite and similar synthetic phenol and cresol products, and in celluloid or pyroxylin plastics. The oxide is also used as a pigment in the manufacture of linoleum, coated textiles, rubber, wall-papers, printing ink, glass, ceramic glazes and enamel-ware. Titanium in chrome-nickel steel reduces intergranular corrosion. The tetrachloride is used for smoke screens, and the bichloride and sulphate in the dye industry.

Ilmenite, in Bihar, forms one of the constituents of the vanadium-bearing titaniferous iron-ores of southern Dhalbhum, described in Chapter XXXIV. These ores contain from 10 percent to 25 percent of TiO_2, which is low-grade compared with the ilmenite sands of Travancore.

Massive ilmenite has been recorded from the foot of the hills to the W. N. W. of Manbazar (22° 04′: 86° 40′) and in quartz veins near Supur (23° 01′: 86° 52′) in Manbhum. Specimens of ilmenite are sometimes found in the pegmatites of the mica belt; loose ilmenite crystals scattered from weathered pegmatites are found around Bara Chuan (24° 34′: 85° 32′) in Gaya district.

Rutile has been found as scattered crystals close to the kyanite deposits near Salbani (23° 04′: 86° 17′) in Manbhum, and near the Kharsawan-Singhbhum deposits, particularly at Lapsa Buru. These are merely of mineralogical interest, however.

At present the titanium minerals of Bihar have no economic value. If, however, the treatment of the vanadium-ores of south Dhalbhum should ever become a commercial proposition, then the extraction also of the TiO_2 from these low-grade ores may be possible. Similarly, it may prove possible to extract also the high TiO_2 content of some of the Bihar bauxites during their treatment for alumina.

1. Ball, V. Geology of the districts of Manbhum and Singhbhum. *Mem. Geol. Surv. India*, XVIII, p. 107, 1881.

2. Ball, V. Manual of the economic geology of India, Part III, p. 323, 1881.

3. Dunn, J. A. and Dey, A. K. Vanadium-bearing titaniferous iron-ores in Singhbhum and Mayurbhanj, India. *Trans. Min. Geol. Inst. India*, XXXI (3), 1937.

4. Dunn, J. A. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*, LXIX (1), p. 214-223, 1937.

Topaz.

The mineral topaz has been found associated with kyanite-rock in Singhbhum. It appears to have no deleterious effect on the

usefulness of kyanite as, at the high temperature at which the latter is calcined, the fluorine content of the topaz is driven off. It is possible that topaz may be useful to the glass industry for the manufacture of special glasses.

Perhaps the best deposit of topaz-rock is to the southeast of Lapsa Buru in Kharsawan State, but in Singhbhum topaz-rock has been mined at Ghagidih (22° 45′: 86° 11′).

1. Dunn, J. A. The aluminous refractory materials: kyanite sillimanite and corundum in northern India. *Mem. Geol. Surv. India*, LII (2), pp. 215-242, 1929.
2. Dunn, J. A. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*, LXIX (1), pp. 38, 232-33, 1937.

Triplite.

The phosphate and fluoride of manganese and iron, triplite, which contains 32 percent of phosphoric acid, has been recorded from two mica mines in Gaya district. At the Abraki Pahar mine, two miles southeast of Singar (24° 34′: 85° 30′), it was found associated with pitchblende, and 10 tons were extracted in 1914. The other occurrence was Pichhli (24° 36′: 85° 27′) 3 miles northeast of Singar. Both of these occurrences were entirely fortuitous and should not be regarded as having any future economic importance.

1. Holland, T. H. The mica deposits of India. *Mem. Geol. Surv. India*, XXIV, p. 51, 1902.
2. Tipper, G. H. On pitchblende, monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. *Rec. Geol. Surv. India*, L, pp. 255-262, 1919.

Uranium minerals.

At the Abraki Pahar mica mine near Singar, in Gaya district, pitchblende was found at various times early this century. It was associated with triplite and yellow uranium ochre, the latter presumably being due to alteration of the pitchblende. According to Burton, the mineral occurred as nodules in a pegmatite which was 40 yards wide and 350 yards in length(1), but most of the pitchblende was obtained from a single pit. The largest nodule weighed 36 lbs. About 6 cwt. had been found up to 1913, and a further 16 lbs. in 1914. Rare torbernite and autunite also occurred(2).

Specimens of the copper uranium phosphate, torbernite, have been recorded from Sungri (22° 27′: 86° 33′) in Dhalbhum along with a little uranium ochre(3).

1. Hayden, H. H. General report of the Geological Survey of India for the year 1913. *Rec. Geol. Surv. India*, XLIV, p. 24, 1914.
2. Tipper, G. H. On pitchblende, monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. *Rec. Geol. Surv. India*, L, pp. 255-262, 1919.
3. Dunn, J. A. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*. LXIX (1), p. 39, 1937.

Wolfram.

Between 1916-1918 a small vein of wolfram was mined on the northern side of a small hill close to Tatanagar railway station. The vein occurred between quartzite and mica-schists, dipping 40° to N 35° E. It was mined to a depth of 100 feet, from an inclined shaft. The vein never exceeded 6 inches in thickness and was often only a fraction of an inch; it still persisted at the bottom of the workings, although very narrow. A total of 30·5 tons of wolfram was obtained.

It would not be advisable to reopen this vein in the future. The mine was never payable and only such a time of war stress could have prompted the venture.

1. H. H. Hayden. General report for 1918. *Rec. Geol. Surv. India*, L, p. 20, 1919.
2. L. L. Fermor. The mineral resources of Bihar and Orissa. *Rec. Geol. Surv. India*, LIII, p. 305, 1921.
3. J. A. Dunn. The mineral deposits of Eastern Singhbhum and surrounding areas. *Mem. Geol. Surv. India*, LXIX (1), p. 137, 1937.

Zinc.

The only occurrences of zinc in Bihar are the small quantities associated with the lead-copper-ores of Bhairukhi in Santal Parganas, and with the copper-ores of Baragunda and of Patru nadi in Hazaribagh district. There are no deposits of economic value.

LOCALITY AND MINERAL INDEX.

BHAGALPUR DISTRICT.

Minerals: Building materials, clays (kaolin), lead and silver, mica, sand, fuller's earth.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Chromite . .	Baida Chauk. . .	24 46	87 02	97.
Clay (kaolin) . .	Colgong . . .	25 16	87 14	104.
	Kasdeh . . .	25 18	87 17	104.
	Letwabaran . . .	24 39	86 51	104.
	Patharghatta hill . .	25 20	87 16	103, 104.
	Samukhi . . .	24 57	86 52	104.
Glass sand . .	Patharghatta hill . .	25 20	87 16	134.
Lead and silver .	Dudhijarna . . .	24 53	86 45	162.
	Phaga	24 46	86 56	162.
	Gonora . . .	?	?	162.
	Kajuria . . .	24 42	86 44	162.
	Kharikhar . . .	24 50	86 45	162.
	Karda . . .	24 41	86 43	162.
Occurrences of little or no importance—*fuller's earth* . .	Patharghatta hill . .	25 20	87 17	231.

CHAMPARAN DISTRICT.

Minerals : Saltpetre, sodium salts.

DARBHANGA DISTRICT.

Minerals Saltpetre, sodium salts.

GAYA DISTRICT.

Minerals. Alkali salts (saltpetre, sodium salts), barytes, building materials, clay (kaolin), mica, mineral pigments, mineral waters, sand, sulphate (ammonium), columbite and tantalite, monazite, quartz crystals, triplite, uranium minerals.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Barytes . . .	Bramjan hill . .	24 46	84 59	80.
Clay (kaolin) . .	Kauakol . . .	24 51	85 53	104.
Mineral pigments .	Gaya (W. of) . .	24 47	85 00	194.
Mineral waters .	Agni Khund . .	25 00	85 30	199, 200, 201, 202.
	Tapoban—			
	Brahma Khund . .	24 55	85 19	198, 200, 202.
Potstone . .	Rajghir hills . .	..	..	220.
	Barabar hills . .	..	..	20.
Occurrences of little or no importance—				
ammonium sulphate .	Hanriya . . .	24 57	85 24	228.
columbite and tantalite	Singar (Abraki Pahar) .	24 34	85 30	229.
monazite . .	Abraki Pahar . .	24 34	85 30	230, 233.
	Pichhli . . .	24 36	85 27	233.
titanium . . .	Bara Chuan . . .	24 34	85 32	236.
triplite . . .	Abraki Pahar . .	24 34	85 30	237.
	Pichhli . . .	24 36	85 27	233.
uranium . .	Abraki Pahar . .	24 34	85 30	237.

HAZARIBAGH DISTRICT.

Minerals: Abrasives (garnet, quartz), building materials, clay (fireclay), coal, copper, glass sands, iron-ore, lead and silvei, limestone, mica, mineral waters, sand, steatite, antimony, arsenic, beryl, columbite, corundum, rose quartz, molybdenite, quartz crystals, tin-ore.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Clay (fireclay)	Emlo	23 48	86 00	104.
Coal	Bokaro coalfield	..	..	112, 116, 119, 120.
	Bokaro	23 47	85 58	116.
	Chandrapura Rly. Station	23 45	86 07	112.
	Chope coalfield	..	..	112, 117.
	Chope	24 02	85 14	117.
	Giridih coalfield	..	..	112, 118, 119, 120.
	Giridih	24 12	86 18	118.
	Itkhori coalfield	..	..	118.
	Itkuri	24 18	85 10	118.
	North Karanpura coalfield	..	..	112, 117.
	South Karanpura coalfield	..	..	112, 117.
	Ramgarh coalfield	..	..	112, 116.
Copper	Baragunda	24 05	86 04	128, 129, 130.
	Golgo	24 24	86 22	129.
Glass sands	Bokaro coalfield	..	..	134.
Iron-ore	Bokaro coalfield	..	..	148.
	Karanpura coalfield	..	..	148.
	Ramgarh coalfield	..	..	148.

HAZARIBAGH DISTRICT—*contd.*

HAZARIBAGH DISTRICT—*concld.*

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Mineral waters—*contd.*	Kawa Gandhawani .	23 44	85 23	199—203.
	Kesodih . . .	24 12	86 02	199.
	Lachman Khund .	24 09	85 38	202.
	Sita Khund . . .	24 09	85 38	202.
	Suraj Khund . .	24 09	85 38	199, 201—203.
Steatite . . .	Parasnath (W. of) .	23 58	86 08	220.
Deposits of little or no importance—				
antimony . .	Hisatu. . . .	24 00	85 01	228.
columbite . .	Kodarma Reserved Forest . . .	..	..	230.
corundum . .	Tutki Ghat . .	23 57	85 42	230.
beryl . . .	Muhawar Hill (S. of) .	24 43	85 46	231.
rose quartz . .	Parsabad . . .	24 19	85 45	92, 232.
molybdenite . .	Baragunda . . .	24 05	86 03	233.
	? Amra (near Dumri) .	23 59	85 59	233.
	Mahabank . . .	24 24	86 23	233.
tin-ore . . .	Chappatand . .	24 40	85 57	234.
	Pihra	24 39	85 49	234.
	Purgo	24 10	86 08	234.
	Simratanri . . .	24 39	85 47	234.
zinc . . .	Baragunda . . .	24 05	86 04	238.
	Golgo	24 24	86 22	238.

MANBHUM DISTRICT.

Minerals: Abrasives (chert), asbestos, barytes, building materials, clays (fireclay and china clay), coal, copper, glass sands, gold, iron-ore, kyanite, lead and silver, limestone, manganese, mica, mineral pigments, mineral waters, sand, steatite, apatite, bismuth, corundum, titanium.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Abrasive (chert)	Chandil	22 57	86 04	68.
Asbestos . .	Mahulbasa . . .	22 51	86 19	78.
Barytes . . .	Malthol . . .	23 26	86 26	80.
	Purulia . . .	23 20	86 22	80.
Building stones (epidosite)	Jate . . .	22 55	85 16	91.
	Sekradih . . .	22 54	85 50	91.
Clays—				
fireclay . .	Birsinghpur . . .	23 47	86 44	105.
	Brindabanpur . .	23 34	86 46	105.
	Chandkuiya . . .	23 45	86 28	105.
	Chhatabar . . .	23 45	86 44	105.
	Chirkunda . . .	23 44	86 48	105.
	Jharia station . .	..	..	102.
	Kapasara . . .	23 46	86 45	105.
	Ketharidih . . .	23 44	86 28	105.
	Kumardhubi . .	23 45	86 47	101, 105.
	Makunda . . .	23 44	86 28	105.
	Marmah . . .	23 46	86 45	105.
	Mera	23 45	86 48	105.
	Mugma . . .	23 45	86 45	105.

MANBHUM DISTRICT—*contd.*

Mineral.	Place.	Latitude.	Longitude.	Page.
Clays—*contd.*		° ′	° ′	
fireclay—contd.	Palasia . . .	23 44	86 45	105.
	Parbad . . .	23 42	86 27	105.
	Pathardih Station .	23 40	86 26	102.
	Patlabari . . .	23 43	86 45	101.
	Rajpura . . .	23 46	86 46	105.
	Sangamahal . .	23 45	86 44	105.
	Sulunga . . .	23 43	86 28	105.
	Tetulmari Rly. Station .	23 49	86 20	105.
china clay . .	Balrampur . . .	22 59	86 38	105.
	Dandudih . . .	23 59	86 33	105.
	Katras. . . .	23 48	86 21	105.
	Rajabasa . . .	22 49	86 29	105.
	Taldih . . .	23 24	85 56	105.
	Tamakhun . . .	22 59	86 36	105.
	Tundi	23 59	86 27	105.
Coal	Chandrapura coalfield .	..	..	112, 115.
	Jharia coalfield . .	..	..	112, 114, 115, 119, 120.
	Raniganj coalfield .	..	..	112, 113, 119, 120.
Copper . . .	Kalyanpur . . .	23 02	86 02	129.
	Kantagora . . .	22 58	86 42	129.
	Punda . . .	22 59	86 40	129.
	Tamakhun . . .	22 59	86 36	129.

MANBHUM DISTRICT—*contd.*

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Gold . . .	Burudih . . .	23	02	85	51	138.
	Ichadih . . .	23	02	85	57	138, 139, 140.
	Lawa	23	01	86	05	138, 139.
	Subarnarekha river .	..		..		137, 138.
Iron-ore . . .	Asanpani . . .	22	46	86	27	147.
	Beharinath . . .	23	35	86	57	148.
	Jharia coalfield . .	..		..		148.
	Raniganj coalfield .	..		..		148.
	Tamakhun . . .	22	59	86	35	147.
	Teludih . . .	23	34	86	57	148.
Titaniferous iron-ore .	Manbazar . . .	23	03	86	43	148.
Kyanite . . .	Ichadih . . .	23	04	86	10	157.
	Salbani . . .	23	04	86	17	157.
Lead and silver .	Beldi	23	03	86	18	160, 161.
	Dhadka . . .	22	48	86	30	161.
	Ghagra . . .	22	49	86	34	161.
	Janijhor . . .	22	48	86	32	161.
	Kushbani . . .	22	48	86	34	161.
	Malthol . . .	23	26	86	26	161.
	Nanna . . .	22	47	86	35	161.
	Panra or Parada . .	22	49	86	35	161.
Limestone . . .	Asta	22	38	86	40	166.
	Baghmara . . .	23	39	86	45	172.

MANBHUM DISTRICT—*contd.*

MANBHUM DISTRICT—*concld.*

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Mineral pigments .	Chandil (W. & S. E. of)	22 57	86 04	194.
	Gangokocha . .	22 54	85 59	195.
	Rajabasa . . .	22 49	86 24	194.
Mineral waters .	Sheopur or Sarsa Khund	23 40	86 35	200.
	Tathi	23 41	86 48	200.
Refractory materials—				
fireclay . .	see under Clays.			
graphite . .	Dimadiha . . .	23 29	86 09	210.
steatite . .	see under Steatite.			
Steatite . . .	Maysara . .	23 04	86 00	219.
	Khusbani . . .	22 48	86 34	219.
	Pandra . . .	23 48	86 43	220.
	Pukhurkata . . .	22 52	86 38	219.
Occurrences of little or no importance—				
apatite . .	Malthol . . .	23 26	86 26	231.
bismuth . .	Malthol . . .	23 26	86 26	229.
corundum . .	Salbani . . .	23 04	86 17	230, 231.
titanium . .	Manbazar (W. N W. of)	23 04	86 40	236.
	Salbani . . .	23 04	86 17	236.
	Supur	23 01	86 52	236.
platinum . .	Gurma nadi (near Dhadka)	22 48	86 30	233.

MONGHYR DISTRICT.

Minerals: Alkali salts (saltpetre, sodium salts), asbestos, bauxite, building materials, clays (fireclay, kaolin), glass sands, lead, manganese, mica, mineral waters, refractory materials (clays, silica), sand.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Asbestos . .	Goria Koh ghat . Ghorakhor hill .	25 12	86 31	79.
	Pirpahar hill . .	25 23	86 31	79.
Building materials—				
slate . . .	Kharagpur hills . .	..	..	90.
quartzite . .	Dharhara . . .	25 15	86 24	89.
Clay—*fireclay* . .	Monghyr . . .	25 22	86 28	102, 105.
	Pirpahar . . .	25 23	86 31	102, 105.
china clay .	Nawadih . . .	24 47	86 23	105.
Lead . . .	Kharagpur hills . .	..	..	162.
	Chakai hills . .	..	..	162.
Manganese . .	Katnowa hills . .	24 57	86 16	176.
	Pandipahari hills . .	?	?	176.
Mineral waters .	Bhurka . . .	?25 18	?86 37	199.
	Bhimabandh . .	25 04	86 24	199.
	Janam Khund . .	25 07	86 24	199.
	Kharagpur hills . .	25 07	86 33	199.
	Lachmi Khund . .	?25 03	?86 29	199.
	Panchbhur . . .	25 06	86 15	199.

MONGHYR DISTRICT—*contd.*

MUZAFFARPUR DISTRICT.

Minerals: Saltpetre, sodium salts

PALAMAU DISTRICT.

Minerals: Bauxite, building materials, clays, coal, dolomite, iron-ore, lead-silver, limestone, mica, mineral springs, refractory materials, sand, gemstones (diamonds, garnets).

Mineral.	Place.	Latitude.	Longitude	Page.
		° ′	° ′	
Bauxite . . .	Mahuadand . . .	23 24	84 07	85.
	Netarhat . . .	23 28	84 16	84, 85.
Clay . . .	Japla	24 32	84 03	88.
	Rajhara . . .	24 10	84 02	101, 102, 106.
Coal . . .	Auranga coalfield . .	..	..	112, 117.
	Daltonganj coalfield .	..	..	112, 117.
	Daltonganj . . .	24 02	84 04	177.
	Hutar coalfield . .	..	..	112, 117.
	Hutar	23 59	84 11	117.
	Rajhara . .	24 10	84 02	117.
Iron-ore . . .	Auranga coalfield .	..	..	148.
	Gore Pahar . . .	23 58	83 58	148
	Sua	24 00	84 06	148.
Lead-silver . .	Bankhap . . .	23 59	84 49	161.
Limestone . .	Bakoria . . .	23 54	84 19	167.
	Ban Pahar . . .	23 59	83 59	167.
	Daltonganj (S. W. of) .	24 02	84 04	92, 172.
	Diridag . . .	23 50	84 43	169.
	Majhauli . . .	24 10	84 08	167.
	Olhepat . . .	23 50	84 44	167, 169.
	Pandwa . . .	24 10	84 04	167.
	Sua	24 00	84 05	167.

PALAMAU DISTRICT—*contd.*

Mineral.	Place.	Latitude.		Longitude.		Page
		°	′	°	′	
Mica .	Daltonganj . . .	24	02	84	04	183.
	Khorhi . . .	24	02	84	00	183.
	Kini	24	04	84	01	183.
	Leshganj . . .	24	02	84	12	183.
Mineral springs .	Jaram . . .	23	49	84	30	200.
	Kokraha . . .	23	45	84	05	200.
Refractory materials—						
fireclay . .	see under Clay . .					
graphite . .	Arapur . . .	24	14	84	02	210.
	Hatai Khas . . .	24	14	84	01	210.
	Tulbula . . .	24	15	84	02	210.
Occurrences of little or no importance—						
diamonds . .	Simah	23	35	84	17	231

PATNA DISTRICT.

Minerals: Alkali salts, building materials, mineral waters.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Mineral waters .	Rajghir springs— . .	25 01	85 25	197—202.
	Brahma Khund .	..	..	202.
	Chandrama Khund .	..	..	202.
	Ganga Khund . .	..	..	202.
	Jamuna Khund .	..	..	202.
	Makhdum Khund .	..	..	197, 202.
	Markandya Khund .	..	..	202.
	Ram Khund . .	..	..	202.
	Sita Khund . .	..	..	202.
	Suraj Khund . .	..	..	202.
	Viswamitra Khund .	..	..	197, 202.
	Vyas Khund . .	..	..	202.

PURNEA DISTRICT.

Minerals : Building materials.

RANCHI DISTRICT.

Minerals: Asbestos, barytes, bauxite, building materials, Chromite, clay (lithomarge), gold, lead-silver, limestone, mica, mineral pigments, steatite, fuller's earth.

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Asbestos . .	Itki	23	21	85	08	79.
Barytes . . .	Bahea	23	23	85	29	80.
	Bongabera . . .	23	21	85	31	80.
	Silwai	23	22	85	26	80.
Bauxite . . .	Bagru Pat . . .	23	29	84	36	84, 85.
	Banda Pat . . .	23	22	84	32	85.
	Banjari Pat . . .	23	22	84	30	85.
	Bar Pat . . .	23	17	84	26	85.
	Chapuadhea Pat . .	23	28	84	34	85.
	Dudha Pat . . .	23	25	84	30	84, 85.
	Khamar Pat . .	23	37	84	41	84, 85.
	Kutcha Pat . . .	23	11	84	20	85.
	Oronga Pat . . .	23	36	84	38	85.
	Pakhar Pat . . .	23	34	84	37	85.
	Pakri Pat . . .	23	23	84	15	85.
	Rajadera . . .	23	17	84	14	84.
	Serendag . . .	23	22	84	28	84, 85.
Building materials—						
epidosite . .	Dasauri . . .	22	56	85	37	91.
	Jate	22	55	85	16	91.
	Rugudih . . .	22	53	85	39	91.
Chromite . .	Hotag Hill, Silli . .	23	21	85	50	97.

RANCHI DISTRICT—*contd.*

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Clay (lithomarge) .	Bagru Pat . . .	23	29	84	36	106.
	Dischmatia Pat . .	23	28	84	37	106.
	Serendag . . .	23	22	84	28	104, 106.
Gold . . .	Sonapet valley . .	23	53	85	40	137, 139.
Lead-silver . .	Kumbakera . . .	22	29	84	45	161.
	Silli	23	21	85	50	161.
	Silwai	23	23	85	27	161.
Limestone . .	Babhane . . .	23	40	85	04	169.
	Dundu	23	40	85	04	168.
	Hoyar . . .	23	39	85	02	169.
	Khalari . . .	23	39	85	00	167, 169.
	Ray	23	41	85	03	167, 168.
Mica . . .	Sikriadanr . . .	22	41	84	29	183.
Mineral pigments .	Kubasa . . .	22	57	85	48	195.
	Kudda	22	57	85	50	195.
	Papirda . . .	22	57	85	39	195.
	Ray	23	41	85	04	195.
	Western Ranchi district.	..		..		195.
Steatite . . .	Bandudih . . .	22	55	85	49	219.
	Kuddadih (N. of) . .	22	53	85	48	219.
Occurrences of little or no importance—						
fuller's earth .	Bagru Pat . . .	23	29	84	36	231.

SANTAL PARGANAS.

Minerals: Building materials, clays (fireclays, china clays), coal, copper, lead-silver, mineral pigments, mineral waters, sand, gemstones (agate, amethyst).

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Building materials—				
trap . . .	Rajmahal hills . .	..	..	90.
Clay—				
fireclay . .	Chuparbhita coalfield .	..	..	107.
	Dhamni coalfield . .	..	..	107.
	Hura	24 59	87 23	107.
	Piarim . . .	25 00	87 24	107.
	Rajmahal hills . .	..	..	106
china clay . .	Bagmara . . .	24 38	87 17	106.
	Baskia . . .	24 27	87 23	106.
	Bhurkunda . . .	24 20	87 21	106.
	Dudhan . . .	24 16	87 24	106.
	Hura	24 59	87 23	102.
	Karanpur . . .	24 20	87 23	106.
	Mangal Hat . . .	25 04	87 51	102, 106.
	Rajabhita . . .	24 56	87 22	106.
	Rajmahal hills . .	..	..	102, 106.
Coal . . .	Bargo	24 30	87 24	119.
	Brahmani coalfield .	..	..	112, 118.
	Chhota Bhorai . .	25 02	87 23	119.
	Chilgo	24 33	87 28	119.

SANTAL PARGANAS—*contd.*

SANTAL PARGANAS—*concld.*

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Mineral waters .	Baramasia . . .	24	31	87	39	200.
	Bhumka . . .	24	02	87	17	200.
	Jharia . . .	24	20	87	42	200.
	Lau-lau-dah . .	24	22	87	43	200.
	Nunbhil . . .	24	05	87	13	200.
	Susumpani . .	24	09	87	17	200.
	Tapatpani ? . . .	24	12	87	21	200.
Refractory materials—						
quartzite .	Jamtara . . .	24	00	86	08	212.
Occurrences of little or no value—						
agate, amethyst .	Berhait . . .	24	53	87	37	231.
zinc . . .	Bhairukhi . . .	24	36	86	36	238.

SARAN DISTRICT.

Minerals: Saltpetre, sodium salts.

SHAHABAD DISTRICT.

Minerals: Abrasives and grinding materials, alkali salts (saltpetre, sodium salts), building materials, glass sands, limestone. mineral pigments, sulphur.

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Building materials—*sandstone* . .	Kaimur hills. . .	..	..	90.
Glass sands . .	Kaimur hills. . .	..	..	135.
Limestone . .	Baulia . . .	24 36	83 55	171, 172.
	Banjari . . .	24 41	83 59	171, 172.
	Chunhattar . . .	24 36	83 52	171.
	Dumarkhar . . .	24 48	83 53	171.
	Margohi . . .	24 52	84 04	171.
	Ramdhira-on-Son . .	24 46	84 02	171.
	Rohtas . . .	24 38	83 55	92, 136, 164.
Mineral pigments .	Chathans . . .	24 38	83 40	195.
	Madpa . . .	24 38	83 30	195.
Refractory materials—				
dolomite . .	Banjari . . .	24 41	83 59	172, 210.
Sulphur . . .	Amjor . . .	24 43	83 59	223.
	Kasisya Koh . .	24 41	83 53	223, 224.
	Yogyaman Koh . .	24 43	83 52	223, 224.
Occurrences of little or no importance—				
ammonium sulphate	Rohtasgarh . . .	24 38	83 55	228.
potstone . .	Pittian . . .	?	?	220.

SINGHBHUM DISTRICT.

Minerals: Abrasives (garnet, quartz), apatite, asbestos, barytes, building materials, chromite, clay (china clay), copper, glass sands, gold, iron-ore, kyanite, lead-silver, manganese, mica, mineral pigments, refractory materials (quartz schist), steatite, vanadium, jasper, quartz crystals.

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Abrasives—						
garnet . . .	Malibani . . .	22	33	86	42	67, 231.
	Shirbai dungri . .	22	20	86	39	67.
chert . . .	Jamda . . .	22	10	85	26	68.
Apatite . . .	Badia	22	29	86	28	74—76.
	Bhadua . . .	22	28	86	30	76.
	Chandar Buru . .	22	43	86	13	75. 76.
	Kanyaluka . . .	22	29	86	31	76.
	Khejurdari . . .	22	24	86	34	73, 75.
	Nandup . . .	22	44	86	12	74—76.
	Patharghara . .	22	32	86	27	73—76.
	Sunrgi . .	22	27	86	33	74—76.
Asbestos . .	Anjedbera Protected Forest . . .	..		..		79.
	Chirutantri . . .	22	24	86	34	78.
	Digarsai . . .	22	35	86	15	78.
	Lipokocha . . .	22	25	86	30	78.
	Mahespur . . .	22	23	86	30	78.
	Manpur . . .	22	36	86	16	78.
	Nurda . . .	22	20	85	44	79.
	Sahedba Reserved Forest	..		..		79.
	Tonto	22	23	85	37	79.

SINGHBHUM DISTRICT—*contd.*

SINGHBHUM DISTRICT—*contd.*

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Copper . . .	Astakoali	22	21	86	29	128.
	Badia	22	29	86	28	126, 127—128.
	Baharagora . . .	22	16	86	43	123, 128.
	Chapri . . .	22	37	86	24	127.
	Charakmara . .	22	17	86	41	128.
	Churia Pahar . .	23	18	86	36	128.
	Dhadkidih . . .	22	44	86	10	126.
	Dhobani . . .	22	31	86	27	125.
	Duarparam . . .	22	46	85	34	123, 126.
	Gohala . . .	22	29	86	30	128.
	Hitku	22	43	86	15	126.
	Jaypur . . .	22	45	85	36	126.
	Jharia . . .	22	18	86	42	128.
	Kanas . . .	22	30	86	31	128.
	Kendadih . . .	22	35	86	25	127.
	Khejurdari . . .	22	24	86	34	128.
	Laukesra . . .	22	33	86	27	127.
	Mundadevata . .	22	18	86	42	128.
	Mushabani (Mosaboni) .	22	31	86	28	123—125, 127—128.
	Nandup . . .	22	44	86	12	126.
	Rajdah . . .	22	41	86	17	126.
	Rakha Mines . .	22	38	86	22	123. 125—127.
	Ramachandra (Chandar) Buru	22	43	86	13	126.
	Roladih . . .	22	45	85	40	126.

SINGHBHUM DISTRICT—*contd.*

SINGHBHUM DISTRICT—*contd.*

Mineral.	Place.	Latitude.	Longitude.	Page.
		° ′	° ′	
Iron-ore—*contd.*	Kudada . . .	22 42	86 12	148.
	Kudlun (N. of) . .	22 47	86 23	147.
	Lukud Buru . .	22 40	85 27	147, 148.
	Noamundi . . .	22 09	85 29	143, 144, 149.
	Notu Buru . . .	22 18	85 22	143.
	Pansira Buru . .	22 18	85 22	143, 145, 150.
	Patharghara . .	22 32	86 27	148.
	Saruda (S. W. of) . .	22 38	85 12	147.
(*Vanadium-bearing iron-ore*) . .	Dublabera . . .	22 29	86 17	148.
Kyanite . . .	Badia	22 30	86 28	157.
	Bakra	22 29	86 29	157.
	Bhakar . . .	22 23	86 36	157.
	Chirugora . . .	22 33	86 31	157.
	Daontanri . . .	22 30	86 09	157.
	Dobha . . .	22 32	86 31	157.
	Ghagidih . . .	22 45	86 11	157.
	Kanyaluka . . .	22 28	86 31	157.
	Mohanpur . . .	22 34	86 32	157.
	Rakha Mines (east ridge)	22 38	86 22	157.
	Shirbai dungri . .	22 21	86 40	157.
	Singpura . . .	22 22	86 35	157.
Lead-silver . .	Pahardia . . .	22 30	85 12	161.
	Sausal . . .	22 37	85 17	161.

SINGHBHUM DISTRICT—*contd.*

SINGHBHUM DISTRICT—*contd.*

Mineral.	Place.	Latitude.		Longitude.		Page.
		°	′	°	′	
Mineral fertilisers—						
potash felspar .	Jainti	22	04	85	41	191.
apatite . .	see under Apatite.					
Mineral pigments .	Basadera . . .	22	40	86	30	195.
	Bicha Buru . . .	22	39	85	24	195.
	Dharadih . . .	22	43	86	32	195.
	Coilkera . . .	22	31	85	23	195.
	Karamta Buru . .	22	40	85	25	195.
	Kharhi dungri . .	22	32	86	45	195.
	Kuira	22	32	85	31	195.
	Leda Buru . . .	22	28	85	22	195.
	Lukud Buru . .	22	40	85	27	195.
	Mahespur (N. of) . .	22	23	86	30	195.
	Mangru . . .	22	29	86	16	195.
	Metiabandi . . .	22	33	86	38	195.
Refractory materials—						
chromite . .	see under Chromite.					
dolomite . .	Putada Spring . .	22	34	85	49	210.
kyanite . .	see under Kyanite.					
magnesite . .	Bhitar Dari . . .	22	41	86	11	209, 211.
quartz-schist . .	Kendadih . . .	22	36	86	26	212.
	Rakha Mines . .	22	38	86	22	212.
steatite . .	see under Steatite.					

SINGHBHUM DISTRICT—*contd.*

SINGHBHUM DISTRICT—*concld.*

EASTERN STATES.

GENERAL INDEX

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